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SPEECH RECOGNITION IN A
COMMAND AND CONTROL
WORKSTATION ENVIRONMENT

by

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Speech Recognition in a Command and Control Workstation Environment

by

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ABSTRACT

This thesis investigates speech recognition in a command and control workstation environment. It discusses the Navy's need for a command and control workstation (CCWS) and the importance of the human interface design. In particular, it evaluates the performance of Stanford Research Institute International (SRI's) 1000 word discrete speech recognizer. The speech board is intended to be used in the Command and Control Multi-Media workstation being developed by SRI. Additionally, it investigates a VOTAN continuous recognizer (currently in use by research and commercial vendors) in an interactive warfare simulation game. The results indicate that speech recognition systems could increase the capability of the commander to input and access information, provide more rapid response to information desired or displayed, and enhance human interaction in the man-machine interface. Past, current, and future speech applications are discussed.

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I. SPEECH RECOGNITION IN A COMMAND AND CONTROL WORKSTATION ENVIRONMENT

A. INTRODUCTION

Ever since the rapid influx of microcomputers, there has been increasing incentive to enhance the productivity of humans. The job of automating routine tasks, acquiring and communicating information, and the very popular intelligent support of decision making are all attempting to exploit the potential of these machines. Of equal importance is the growing effort to enhance the productivity of humans through man-machine interfaces to take advantage of these growing capabilities.

We can exchange information in a variety of methods. Our most efficient communication should be available when we want to communicate information via a computer. It has long been known that speech is the most natural and fastest form of communication for us and therefore, should be considered as the unrivaled interface for system optimization.

Research into automatic speech recognition systems has been ongoing for over thirty years. Automatic Speech Recognition (ASR) is defined as the ability for the computer or device to correctly recognize spoken words and translate that into a predetermined output string to the computer. There are many advantages of using voice input. The most important of these characteristics are freeing the user's hands and eyes for other tasks, employment in low light or dark areas, and the freedom of movement from a specified location.

From this list of advantages, it would be easy for us to let our imaginations wander and generate a listing of thirty or more applications for voice input. Quality control on assembly lines, sorting of packages, office automation, aircraft control, disabled control of wheel chairs, and many more well suited examples could be enumerated. The focus of this work is to examine speech applications in the area of Command and Control and in particular a Command and Control Workstation (CCWS).

B. PURPOSE OF THE THESIS

Even though there have been over 30 different theses accomplished at the Naval Postgraduate School related to speech recognition systems alone, there is little awareness of speech applications in the naval environment. Evaluating state of the art systems and recommending various areas for speech applications in a shipboard environment may raise the awareness of this technology and help to incorporate speech technology in the future designs of man-machine interface. It is without a doubt an area of technology that has far reaching consequences for the commander in the growing age of computers.

C. SUMMARY

This thesis describes the purpose of the CCWS in the Distributed Command Support System and the key role of speech in the human interface. Basic speech technology past, present, and future is described in Chapter III. A description of the experiment used to test the Stanford Research Institute International (SRI) 'Berkeley' 1000-word discrete speech recognizer is presented in Chapter IV. A follow-on experiment utilizing a commercially available VOTAN continuous speech recognizer is described in Chapter V. Finally, conclusions from these experiments and the author's recommendations for additional speech applications in a Command and Control environment are offered.

II. ARCHITECTURAL REQUIREMENTS FOR A COMMAND AND CONTROL WORKSTATION (CCWS)

A. OVERVIEW

This chapter will investigate the needs and the architectural requirements for a Command and Control Workstation (CCWS). The particular workstation this paper will investigate is the SUN Microsystems Computer Model-170 proposed by Stanford Research Institute (SRI) for the U. S. Navy needs. This paper will develop the architectural framework needed above the workstation system and focus on the requirement to include well engineered human interfaces. This is motivated by the immense amount of information flow that this future system will support. Voice recognition is examined as a potential solution to the growing complexity of getting information to the commander.

In every C^2 system there is a commander who sole purpose is to make timely and knowledgeable decisions. An understanding of the commander's decision process is essential to ascertaining what the CCWS must support. Every new technological advance alters the balance of forces and must be carefully considered. The CCWS design seeks to create an advantage by integrating a multitude of sources into one system. The commander must be able to exercise control over these combined resources. He must obtain the various data in a form that he can best digest. This is not a trivial problem as the amount of information available to him can quickly overwhelm his staff and work against their objective. It requires a *systems approach* in solving the problem of fusing these composite sources of data. In any systems approach one must understand how the system will compliment the architectural level above and the layer below. We will begin with the definition of some relevant terms and an examination of the processes and structures germane to the CCWS.

Much has been written to define Command and Control (C^2) in various sources. In lieu of adding another definition to the growing mass we will use the Joint Chief of Staffs Dictionary to delineate C^2.

> The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission. Command and control functions are performed through an arrangement of personnel, equipment, communication, facilities, procedures which are employed by a commander in planning, directing, and coordinating, and controlling forces and operations in the accomplishment of a mission. (JCS, 1984)

As defined in Dupuy (1986), *command* is the authority vested in an individual of the armed forces for the direction, coordination, control, and administration of military forces, and *control* is the authority exercised by a commander over the activities of subordinate organizations or entities. Since a computer is the heart of CCWS, we will interpret *computer* as a machine which performs electronic, mathematical manipulation of new inputs and existing data to obtain useful outputs in near-real-time.

In the simplest terms Command and Control is a process by which a commander directs his resources to achieve a goal. One of the key resources is the information increasingly provided by a system of computers.

B. THE COMMANDER'S DECISION PROCESS

The commander's primary goal is the accomplishment of the mission. He must be able to assimilate copious amounts of information and data. Based on his understanding of the situation he must then make the split-second decision for which he alone is accountable. The process can be thought of as a continuous loop which observes the effect of the decision on the environment. This outcome will be reflected in the data or information obtained, and the process repeats.

There are many models depicting this reiterative decision process or loop: J. Lawson's model, Boyd's OODA loop mentioned in Orr (1983) and the SHOR paradigm mentioned in Wohl (1981). All of these illustrations are merely extensions of the stimulus response model of classical behaviorists. For simplicity and to align this feedback loop to the basic functions of a shipboard Combat Direction Center, our view of the maritime commander's decision process will be:

- COLLECT--to obtain combat information from all available sources
- PROCESS--to sort, review, appraise, and correlate all information
- DISPLAY--to present the information that best serves the decision maker
- EVALUATE--decide
- DISSEMINATE--distribute the decision

This decision process can be at any level in the command structure. For the Commanding Officer of a ship, Battle Force Commander, or even the Fleet Commander, the process is the same. These loops are nested within each other forming a hierarchy. The systems and processes that makeup these nested loops all work toward supporting the commander in directing and controlling his forces. The design of a C^2 system must support all these processes in a timely and accurate manner. To motivate an understanding of the factors needed in today's information systems, we will briefly examine the background leading to the current dilemma in information management for the U.S. Navy maritime commander.

C. NAVY NEED

1. Brief History

A primary input to the commander's decision process is monitoring the environment. This process within the decision loop is supported by proper management of his sensors (collection), the processing of this information (process), and presenting the information useful to the decision maker (display). Historically, the tactical commander relied solely on the organic sensors of his battle group. Information from the Fleet Command or other sources was spotty at best. In the 40's and 50's, the technological improvements in sensors and communications equipment produced a huge amount of information for the commander. There was an early indication that the unsupported decision maker could easily be overwhelmed. As pointed out by G. A. Miller (1956) in a psychological review ". . . current manual methods of information processing incident to decision making may be inadequate, and new types of filtering and preplanning will be required." (Wohl, 1981)

Through the years following, the need for a device to assist the commander became even more apparent. The technological advances in computers, automatic data processing and weaponry were overwhelming. The effect of longer range and faster aircraft, missiles, and guns was to greatly increase the area of responsibility for the commander. The protection of his force utilizing the *'Defense-in-Depth'* concept, consisting of a surveillance area, engagement area, and a vital area, was degraded by his inability to manually track all the contacts in these areas effectively. Our systems were quite inadequate to fully support the decision maker. Even the Soviets realized this dilemma as evidenced in this quote from the General of the Army S.M. Shtmenko, U.S.S.R :

> The volume of information that staffs must process has increased many fold since World War II and the time allowed for decision making has decreased many fold. As a result the requirements on the "brain capacity" of commanders and staffs have increased vastly. To meet these requirements by simply expanding the administrative apparatus is fundamentally impossible . . . . The only escape from this incompatible situation lies in the extensive application of automation, primarily computers . . . a "man-machine" system is more perfect than "man" alone or "machine" alone . . . . Information technology does not simply help the commander and his staff, but also stimulates the development of collective military creativity, in which the largest group of people, including those separated by great distances, can participate. (Druzhinin, 1972)

2. **Current Deficiencies in U. S. Navy Information Processing**

The U.S. Navy realized by the end of World War II that the current combat information center (CIC) was quickly becoming outdated. The early 1960s saw the first digital computer, Naval Tactical Data System (NTDS) operational in the fleet. This was a revolutionary step. A machine had been connected, through communications links, to another machine to pass real-time information in a operational environment. NTDS is an automated method of collecting, processing, displaying, and disseminating tactical information. Information is displayed graphically, in real-time and provides the shipboard decision maker with a considerable amount of information to direct his weapon employment. As time progressed, there were tremendous advantages realized in obtaining information from other than organic battle group sources (e.g., national level sensors). This led to many ad hoc improvements to the system that were outside of the original architecture for NTDS and were never really designed to interface with the system. Naturally, *saturation* became a problem. There were so many different systems that often sailors were required to accommodate the differences in data format, information fusion, and sanitization of highly classified data and sources. The problem was summarized in Local Command Center Network Statement of Work (LCCN) (1978) as follows:

> The introduction of each new technology development (communications, weapons, sensors, electronic warfare), whether by enemy or friendly forces, may significantly alter the manner in which multiple platforms (ships, aircraft and submarines) can be most effectively coordinated. The proper exercise of command and control in this changing environment requires that the combined sources of data be presented to the commander in a form which is tailored to his resources, mission, and surrounding environment.

3. Systems Approach

The ad hoc solutions to these problems of coordination and interfacing were complicating rather than supporting the commander's decisions. The increased sophistication of existing systems and the addition of new requirements have caused the individual number of components in systems to drastically increase. A systems approach to effectively manage and assess the expanding individual systems becomes quite evident.

The large quantity of information from national, joint, and or Navy sensors is indispensable to the commanders in the field. The extended battle group surveillance area has grown proportionally to the range of the over-the-horizon weapons (both the enemy's and our own) and global sensors. This vital data is available from many sources, but the current flow of information makes it unobtainable. The information that is available often requires manual correlation. As a result, the decision process discussed above either lacks the necessary information or is overwhelmed by the reams of unprocessed data. The intent of the Distributed Command Support (DCS) System is to reduce the information processing and collection load through correlation, tracking, and fusion of data.

D. SOLUTIONS: A NATIONAL LEVEL DISTRIBUTED COMMAND SUPPORT (DCS) SYSTEM

As defined by Tanenbaum (1981), a *distributed system* is a special case of a computer network with a high degree of connectivity, cohesiveness, and transparency. It could be a stand alone system or one in which the data and information are available to anyone in the network wherever they may be located. Its application in a C^2 environment has far reaching consequences.

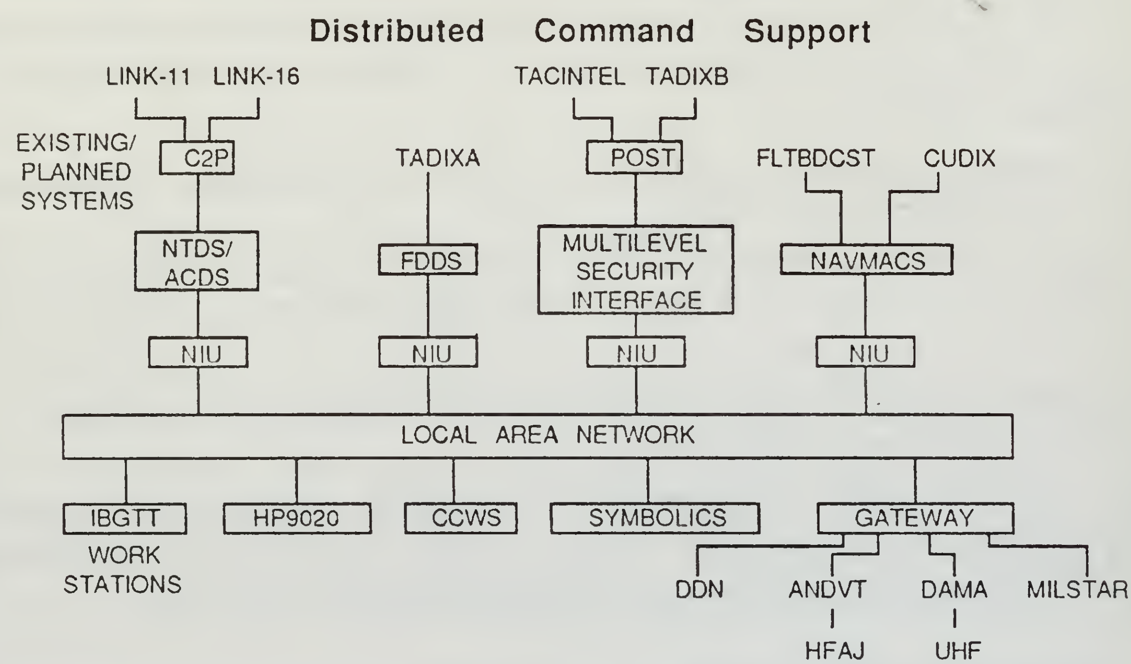
The Navy understood its deficiencies in information exchange and the potential in computer networks. The need for such a system was expressed in the following Naval Need statement by Naval Ocean Systems Command (NOSC, 1985):

> Existing and planned Navy Systems (e.g., sensors, communications, weapons and C2 support systems) are developed as stand-alone systems. Coordination and interpretation between systems is accomplished is an ad hoc, system unique manner that often requires manual coordination. Advances in weapons, surveillance and detection systems are significantly increasing demands on the Navy C2 systems. Therefore, these systems must be integrated in a more adaptable, interoperable and survivable way.
>
> The Distributed Command Support System (DCS) will provide the command centers with a more complete and overall combat picture from both afloat and ashore sources. Through DCS, commanders will be provided with the capability to extract information from data transfer systems, combine that data with artificial intelligence decision aids, and selectively present combat planning decision aids using communication protocols . . . .

The essence of the problem is the *integration* of a wide assortment of computers and software. A non-degraded operation between systems as well as a stand alone capability was envisioned. The DCS network as detailed by NOSC is shown in Figure 1.1

The DCS system is the integration of a wide variety of systems from an assortment of users all able to share each others contributions to the network. Many of these systems already exist with several planned for the near future (FY 87, 88).

The Local Area Network (LAN) is the heart of the system and has many different methods to establish connections (e.g., satellite, high frequency, ultra high frequency and Department of Defense Network (DDN)).



ACDS Advanced Combat Data Systems
ANDVT Advanced Narrowband Digital Voice Terminal
C2P Command and Control Processor
CUDIX Common User Digital Information Exchange System
DAMA Demand Assignment Multiple Access
DDN Defense Data Network
FDDS Flag Data Display Systeml
FLTBDCST Fleet Broadcast
HFAJ High Frequency Anti-Jam
IBGTT Interactive Battle Group Tactical Trainer
LINK 11 Two-way Tactical Data Link NAVY
MILSTAR Military Satellite Communications System
LINK 16 Two-way Tactical DataLink AF
NAVMACS Navy Message Automated Communications System
NIU Network Interface Unit
NTDS Navy Tactical Data System
POST Prototype Ocean Surveillance Terminal
TACINTEL Tactical Intelligence
TADIXA Tactical Data Information Exchange A
TADIXB Tactical Data Information Exchange B
UHF Ultra-HIgh Frequency

Figure 1.1 Distributed Command Support.

Computer to computer systems cannot communicate unless they are compatible, for instance, operating with the same protocols. If they are not, a scheme must be developed to connect them and at the same time minimize the effect of the changing protocols on processing speed. "The key to DCS is the development of standard application protocols that will support intra- and inter-platform computer to computer tasking." (NOSC, 1985) As shown in Figure 1.1, the NIUs or Network Interface Units are used to convert the protocols of one system to be compatible with another. NIU is analogous to the gateway shown at the bottom of Figure 1.1. The difference is that a gateway may be capable of connecting two or more networks.

E. FLEET AND BATTLE GROUP LEVEL: CCWS

As shown in Figure 1.1, the CCWS is an integral part of this network. This is where the commander interfaces to the system and as such is the focus of the rest of this thesis. It will receive all the information on the network. A secure computing project will make it possible for all the users to have the same data base but have access only to those data elements for which they have the security and need requirements. The use of a *trusted* guard will control the access to the data base and allow secure operation of the system with various levels of classification. For example, the Fleet Commander may have global access and unlimited security eligibility while the squadron commander will have theater coverage and security access for only specific areas. The major advantage is that the entire data base will be in every location increasing the connectivity and cohesiveness of the information.

The desirability of personal computing techniques utilizing a distributed workstation environment for the support of command and control operations for the U.S. Navy was formally initiated in early July 1980. SRI International was tasked with a feasibility study. Computer systems and technology has significantly changed since the initial study; however, the basic capabilities and design considerations have remained intact. The capabilities of a workstation in a Command and Control distributed network as pointed out by Poggio (1985) should be :

- The expeditious acquisition of up-to-date multi-media information
- Flexible, reliable, timely exchange of information among people, and between people and processes.
- Rapid match of information transport requirements to dynamic communication capacity
- Survivability - loosely coupled autonomous systems

These capabilities translate directly into the Distributed Command System and a battle group environment. The intelligence gathered from outside sources would be combined with the sensor information provided from the battle group's organic equipments. The capability for many users to simultaneously plan, decide, and disseminate information in a multi-media environment will greatly enhance the commander's decision process.

In addition to network information, the system is designed to provide decision support systems to aid the commander in the decision process. Refering to our model of the decision process shown in Figure 1.2, one can readily see that the CCWS supports all four of the five functions and assists the actual commander's decision. Today's Battle Group Commander should have at his disposal all the available information utilizing the technological hardware and software to make the correct decisions or evaluations. Therefore, to support the commander we should allow the computer to do what it can do best (i.e., fusion of data) and allow the human to do what only he can do, make the decisions. SRI is incorporating these ideas into a computer based multi-media information system. The current design of the workstation plans to accommodate this arrangement.

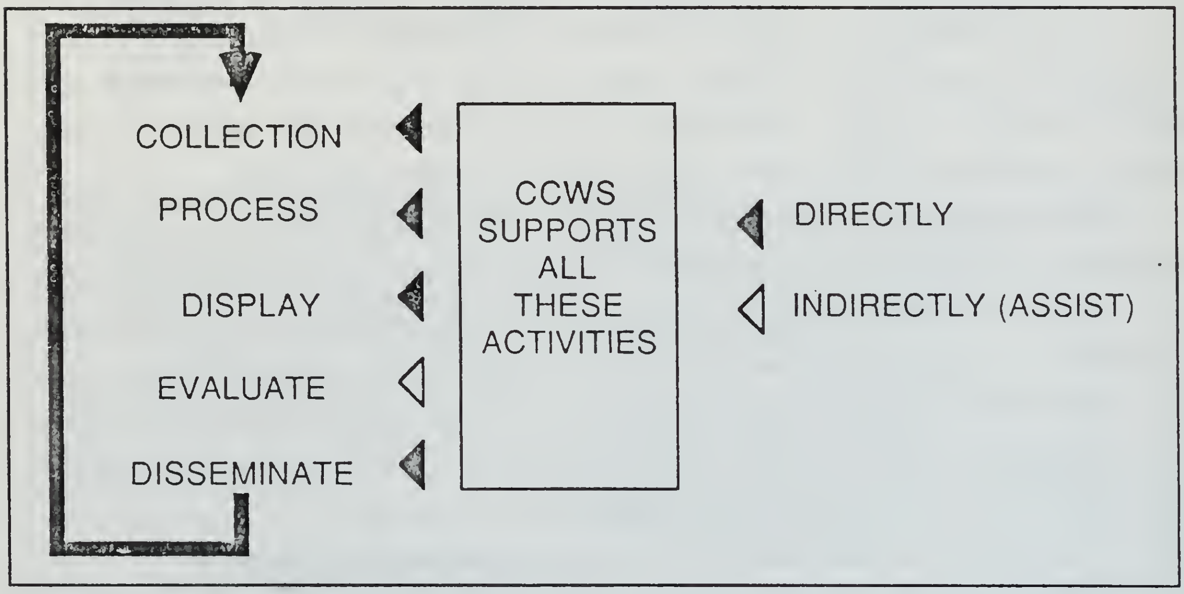


Figure 1.2 Functional View of the Commander's Decision Process Supported by CCWS.

F. HUMAN INTERFACES TO CCWS

Everything meaningful in the operation, extraction, and manipulation of information available from CCWS results from human interaction with the display.

Since the sole reason for the workstation is to assist and extend the capabilities of the commander, the user interface should be of utmost importance. As stated in NOSC; (1985) ". . . the man-machine interface must be more natural and efficient, readily adaptable to the peculiarities of the user and support multi-media (i.e., voice, graphics, text) messages and information." High resolution, bit-mapped color displays, sophisticated window and cursor controls, and speech recognition are all available *now* for implementation in these personal workstations.

Figure 1.3 taken from Poggio (1985) shows SRI's design considerations for several man-machine interface components. The various instruments by which we communicate instinctively (speaking, pointing, and writing) are all available in these human interfaces. The evaluation and enhancement of the man-machine interface, particularly in the speech realm, is the focus of this thesis.

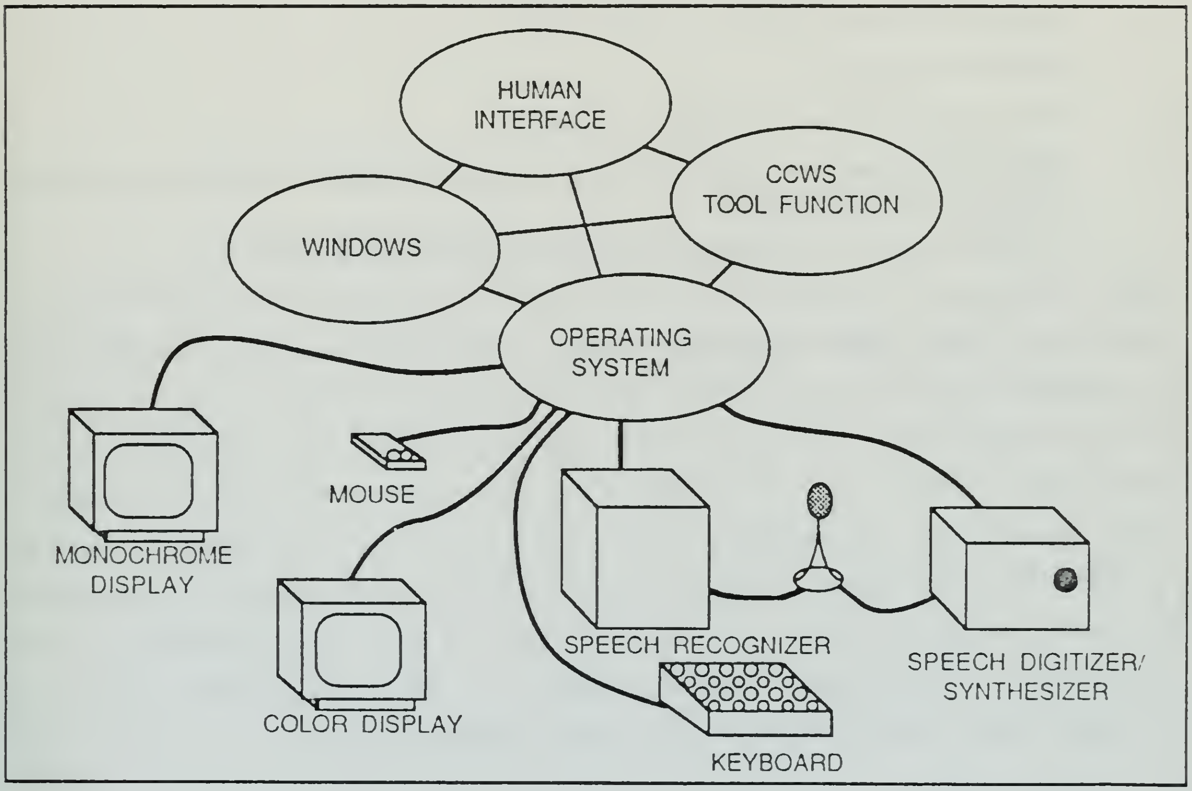


Figure 1.3 CCWS Man-Machine Interface Components (Adapted from Poggio, 1985).

1. Voice Entry

Since humans have such a propensity for talking, it is only logical that speech input/output would be one of the ideal man-machine interfaces. Automatic Speech Recognition (ASR) is defined as the ability for the computer or device to correctly recognize spoken output and translate it into a predetermined output string to the computer. There are many advantages of using voice input. The most important of these advantages is freeing the user's hands and eyes for other tasks, allowing for increased productivity and more rapid system response because speech input is faster than conventional keyboard entry. The incorporation of ASR enables the C^2 system to be a true extension of the commander's decision making ability utilizing current technology, his organization, and its procedures.

2. Automatic Speech Recognition Requirements

The following is a list of the critical requirements necessary in an automatic speech recognizer for incorporation into the CCWS.

- Large vocabulary (capacity > 1000 words).
- Real-time response.
- Very high recognition accuracy (> 98%).
- Adaptable to the user. (i.e., the user should not have to modify or alter his speaking rate significantly)
- No deterioration in accuracy in noisy and stressful environments.

These specifications are believed by the author to be those items necessary for an effective and viable speech recognition system. The minimum capacity of 1000 words was specified since this was a previous goal set in 1971 by the Department of Defense. (Barr and Feigenbaum, 1981) An accurate, versatile, and fast large vocabulary system which adapts readily to any user should be the goal of all manufacturers of automatic speech recognizers. Consequently, this list will be the criteria for final evaluation of the SRI 1000 word discrete recognizer and the VOTAN continuous word recognizer. Since each speech recognizer is different, it is crucial that those responsible for the man-machine interface spend sufficient resources in defining the requirements of a particular system and finding the correct speech system to match.

G. CONCLUSION

The sole purpose of a command and control system is to support the commander's decision process. The current system (NTDS) is overwhelmed by the amount of information it must process and is proliferated with ad hoc equipments that were never really designed to be interfaced with this system. An inadequate system exists for today's commander.

A systems approach utilizing the technological advances in distributed networks and personal computing led to the development of DCS and CCWS. The workstation in development will incorporate the latest in protocols and will focus on supporting the operational commander. The system design is to take full advantage of the man-machine interfaces. Since our fastest and most efficient means of communication is speech, it is only justifiable that the design of the CCWS should consider speech input/output interfaces. This will ensure that the architecture for the command and control workstation is designed to be a true extension of the commander.

III. SPEECH TECHNOLOGY PAST, PRESENT AND FUTURE

A. OVERVIEW

This chapter will describe the basic types of speech recognition systems and a few of the fundamental terms associated with these systems. The history of speech input/output systems and forecasts of the future of speech technology are discussed in broad detail. It is important to realize that each automatic speech recognizer uses different algorithms. The user must be thoroughly familiar with the particular system to ensure that it is the correct equipment for the task and that proper training and programming of the system has been achieved. A basic familiarity with the terms and the types of speech recognition systems is essential in comprehending this rapidly growing technological field.

B. DEFINITION OF TERMS

Before discussing speech recognition systems, we need to define and discuss the various generic types of speech systems. As shown in Figure 2.1 there are two major types: *speaker dependent* and *speaker independent*. A speaker dependent systems relies entirely on the user training the speech recognition system. The user speaks an *utterance* (one or more words in a phrase) usually 1-5 times for each word or a particular output string. The equipment translates the frequency vs. time output into a normalized, digital matrix. Depending on the manufacturer, these may be manipulated by some averaging algorithm or just stored as separate templates in memory or in a data base. A *template* is the digital representation or matrix of the utterance which is used by the device to compare against your spoken word. Each system uses different algorithms to calculate the template and a thorough understanding of the algorithm used by the device is required to maximize recognition through proper training.

When a particular utterance is spoken, it is compared against the template in memory and if it is within a pre-established limit or threshold, the device performs the function the user has installed on the system. If it does not meet the threshold level, the utterance is rejected and nothing is sent by the recognizer. Additionally, there are two other events which can occur: an *insertion* or a *substitution error*. An *insertion* occurs when a recognition takes place due to spurious noise or an utterance other than those that are legitimate entries in the data base. For example, if you said 'defcon' or

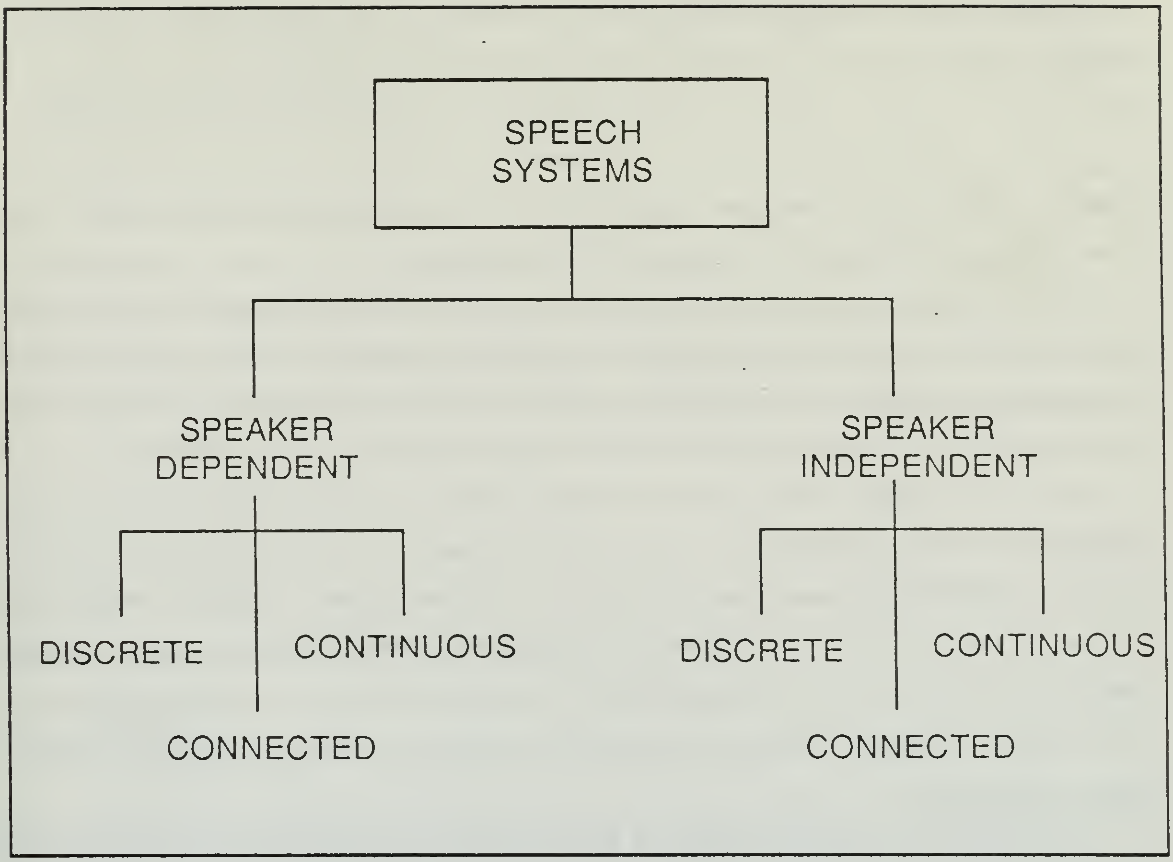


Figure 2.1 Automatic Speech Recognition Systems.

a similar word *NOT* in your database and the system recognizes and outputs the string for 'defense'. A *substitution* on the other hand occurs when your input utterance is calculated as a closer match to a different template in storage, thus incorrectly recognizing another word. For example, if 'defcon' and 'defense' *ARE* currently in the database and the utterance 'defcon' produces the string 'defense'. (Pallett, 1985)

The speaker-dependent, template matching systems are the most common systems on the market. A system trained to a particular individual can achieve recognition accuracies of 90-99 percentile. On the other hand, a *speaker independent* system contains algorithms which are robust enough for any individual to be correctly recognized. Such a device requires no training since each word is represented by templates which are an average of a wide range of different utterances selected by the manufacturer. Depending on the size and limitations of the vocabulary, recognition accuracies are slightly less than those experienced by the speaker dependent systems.

The goal of most speech recognition manufacturers and researchers is to develop a large vocabulary recognizer which is independent of the user. (Poock, 1986b)

Each of these two categories is further subdivided into three separate categories: *discrete*, *connected*, and *continuous*. A *discrete* system or isolated word system as its name implies is one in which the user must pause for a predetermined time (about .1 sec) between consecutive utterances. The device establishes the start and endpoint of the word. These utterances are compared to what is in memory and the output string is sent once the recognizer has calculated the best match.

The *connected* speech system requires no pauses between utterances. The system is continually checking what is spoken and what is in memory. As the word or phrase is recognized, the device is loading that particular string into the output buffer. Once the user pauses, the system unloads all that it has accumulated in the buffer.

In contrast, the *continuous* system outputs the prescribed string immediately upon recognition and does not wait for a pause from the user. Even though there appear to be no apparent word boundaries, the device is able to calculate matches and produce the output strings. This is much harder than discrete recognition since there are major changes which occur in the pronunciation of words at the word boundaries known as *coarticulation*. These are differences in speech patterns not found in isolated or discrete word pronunciation.

Manufacturers today are still not in agreement over exactly what constitutes the difference between these last two types. As stated earlier each and every system is different and must be thoroughly tested and analyzed to ascertain exactly what the manufacturer is trying to represent in his literature.

C. PAST

Many of the larger technical companies like IBM, Philco-Ford, RCA, and Bell Telephone Laboratories started research back in the early 50's and 60's. It was not until the early 70's that the first products commercially available were offered by Threshold Technology, Inc. and Scope Electronics. (Poock, 1986b)

Concurrently in the early 1970's, the U. S. Department of Defense Advanced Research Projects Agency (ARPA) funded a five-year program in speech understanding research (SUR).

> ARPA funded five speech projects and several subcontracts for developing parts of speech-systems. Some of the major ARPA contractors produced multiple systems during the five-year period: Work at Bolt, Beranek and Newman, Inc.

(BBN) produced first *SPEECHLIS* and then *HWIM* (Hear What I Mean), building on earlier BBN research on understanding natural language. Carnegie-Mellon University (C.M.U.) produced the *HEARSEY-I* and *DRAGON* systems in the early development phase (1971-1973) and the *HARPY* and *HEARSEY-II* programs by 1976. SRI International also developed a speech understanding program, partly in collaboration with Systems Development Corporation (SDC). (Barr and Feigenbaum, 1981)

The ARPA projects were all built for the purpose of developing a speech understanding device, but they varied considerably in levels of difficulty, number of speakers, ambient noise, etc. As a result of this effort there was considerable progress made toward practical speech-understanding systems. One of the most important ideas to surface from these projects was the influence of *Artificial Intelligence* (*AI*) research and system architecture. The researchers found *phonetic recognition* was the most promising answer to continuous speech understanding, but at the time they did not have the computing power necessary nor was it as straight forward as initially anticipated. Since the early success of speech recognition used template matching, industry abandoned the harder track of speech phonetics.

D. PRESENT

1. Overview

Currently there are literally thousands of organizations in the United States and around the world exploiting speech systems. From controlling robot arms on the space shuttle to incorporation into children's toys, speech input/output systems are in daily use and are growing rapidly. Despite ARPA's efforts, up until now all the speech systems have consisted of relatively small quantity vocabulary pattern matching or template matching techniques. The better systems can be expected to have recognition accuracies of better than 97%.

There are several periodicals like the *Journal of The American Voice I/O Society* and *Speech Technology Man/Machine Voice Communications* which reflect the latest in research, applications of speech processing, and product reviews. In fact in a recent edition, there were 193 different companies listed providing various products and/or services in the speech field. Speech recognition today is extremely capable and reliable and could be applied to thousands of areas with more awareness and understanding of its benefits to both user and management.

2. Speech Applications in Command and Control

Application of speech recognition systems in a shipboard environment need not stop with the CCWS. There are many other areas where using this technology could be beneficial. In the Combat Direction Center, manipulating NTDS displays and functions on these consoles by voice in conjunction with the trackball tab, computer controlled action entry panel (CCAEP), digital data entry unit (DDEU), and category select panel would allow users to more quickly disseminate information and result in less operator fatigue. Data retrieval by the Commanding Officer or Tactical Action Officer to display decision aids or threat matrices by voice could promote better weapon or countermeasures selections. The automatic speech recognizer could allow the commander to focus totally on the display.

Combat Direction Center is not the only area on the ship that could benefit from speech recognition systems. A voice activated expert system for controlling engineering propulsion plant casualties would greatly enhance the reduced manning policy on the automated gas turbine powered ship classes. Remote activation of damage control (DC) or firefighting equipment by personnel outside the damaged space could reduce the risk of damage to sailors and equipment.

The list could continue. Salfer (1985) presents a more detailed analysis of applications of ASR systems onboard the FFG-7 class ships which could be expanded to include other classes of ships as well. The underlying reason for pointing out various other areas for speech applications is to stimulate awareness and generate other ideas for applications for this technology.

It is important to note regardless of how much faster or better a system can work employing automatic speech recognition technology, if the user and management do not have the motivation to examine such a system, this equipment like others would have no hope for success.

E. FUTURE

Speech recognition in no way should be considered stagnant. Manufacturers and corporations are more than ever wanting to reap the benefits of this technological field. As the awareness and knowledge of this technology becomes more widespread especially in man-machine interface, a greater proliferation of systems will be seen.

The new horizon for speech recognition systems is to move away from template matching schemes to the more flexible *phonetic* recognition. The basis of *phonetic* systems is *phonemes* the basic units of all speech. Once the system is trained on words utilizing all the combinations of phonemes, the formulation of any word is possible. For example this phrase, taken from *Speech Systems Incorporated* advertising literature,

continuous speech development toolkit

would look like this *phonetically*:

kantinyuasspichdivelapmentulkit.

The phonemes are then converted by different syntactic and dictionary builders in a computer which produce the correctly formulated string. At the 1986 *American Voice Input/Output Society* (*AVIOS*) convention, there was only one vendor *Speech Systems Incorporated* who was marketing a *phonetic* recognition system. It is the first commercial system of its type. It is surely the trend of future speech recognition/understanding systems and it is one focus of the Department of Defense funding.

In addition to industrial and university research, Defense Advanced Research Projects Agency (DARPA, formerly ARPA), is sponsoring another multi-million dollar contract titled *Strategic Computing Program*. A major part of the Strategic Computing Program is the integration, transition, and performance evaluation of speech technology. "The speech recognition portion of the Strategic Computing Program is divided into two major areas: continuous speech recognition and robust, connected-word recognition . . ." (Strategic Computing, 1985).

The aim of this program is to make continuous speech recognition a realization. The major thrust would be in the area of *phonetic recognition* to deal with speaker variation, large vocabularies, natural grammars, and real time response. In the area of robust speech recognition, the objectives are to improve upon current system's capacity to deal with variations and distortions of the input speech signal in severe acoustic noise and physiological/psychological stress found in military applications. (Strategic Computing Program, 1985)

Increased use of computers in problem solving will demand more emphasis on man-machine interfaces. Speech recognition will be that interface which makes the computer a true extension of man. We communicate with each other by speech, so it should only be expected we can do the same via a computer. This cursory look at speech types and speech related terminology is meant only to familiarize the reader with terms to be used later and to introduce the ever broadening future of speech input/output systems.

IV. TEST, ANALYZE, AND EVALUATE THE SRI 'BERKELEY' SPEECH BOARD

This chapter describes a series of tests whose purpose was to confirm the voice recognition performance of the SRI *'Berkeley'* board as reported in Murveit (1986). The results of the SRI study suggest that a 1000-word discrete speech recognition system does not sacrifice accuracy despite the high processing speeds necessary for large vocabulary recognition. Their report indicates that the Berkeley speech board system achieved a recognition accuracy of over 90 percent for a 1000 word vocabulary and over 99 percent for a sixteen word vocabulary. In addition this chapter will examine the algorithms used by the speech board for initial template creation, voice recognition, and error correction.

A. DESCRIPTION

SRI selected the *'Berkeley'* board because it was the state of the art in large vocabulary speech recognition. A recognizer of this type was a necessary requirement in a CCWS for a faster and more natural man-machine interface in command entry and database access. Specifically, the research conducted by SRI was for the enhancement of speech interfaces for natural-language data-base-management tools. In cooperation with U.C. Berkeley, SRI modified the design slightly and interfaced it to the SUN-170 Microsystems computer.

B. THE SUN-170 MICROSYSTEMS WORKSTATION

The SUN-170 Microsystem workstation is a UNIX based computer system. These workstations are used in a variety of applications. The value of workstations was realized with the increase in computer power provided by the development of 16 and 32 bit microprocessors. A typical workstation will generally consist of a 1 MIPS (million instructions per second) CPU, 2-4 Megabytes of memory, a high resolution (1000 by 1000 pixels) display, a keyboard, and a mouse. The speech board is interfaced to the SUN and receives the audio input directly.

The workstation used in this experiment is the host computer on the Department of Defense Network (DDN) at address SRI-BOZO. There are several inherent attributes like file transfer protocol (FTP) and telenet (TN) resident on the DDN network which allowed remote work on the vocabulary and data processing from the Naval Postgraduate School.

C. MARA

MARA is the hardware and software components that integrate the speech recognizer into the workstation. The *MARA* system consists of:

- the computer and its programs
- the speech recognizer
- the user

The *MARA* hardware consists of a Multibus PC board, a backplane with a connector, a BNC cable, a pre-amplifier, and a microphone. The software components include:

- The PC board program-*mara86.com*
- The MARA Daemon-*mara*
- The Low Level Recognition command library-*libmara.a*
- The Standard library-*libmara.a*
- Support libraries for various applications-*libmarawindow.a*

The *MARA* system in the broadest sense is the combination of equipment and programs that are referred to as the SRI *'Berkeley'* board. (Kavaler, 1986)

D. THE SRI 'BERKELEY' BOARD

The speech recognition board, as its name implies, is a single circuit board. This board is built with a multibus interface and is modified to be inserted directly into the SUN Microsystems computer workstation. The speech board is divided into two separate subsystems. The *front-end* subsystem manipulates the input into a form to be analyzed by a *comparator* subsystem where the voice templates are stored.

1. Front End

The utterance, in the form of a frequency vs. time signal, enters thru a series of 16 bandpass filters. The outputs are rectified and then low-passed filtered over a period of time. The signal is then divided into 10 millisecond frames. Each frame ". . . is the average voltage a speech signal has in several frequency bands. The system computes speech frames at a rate of one hundred times a second." (Murveit, 1986) During the process of computing the frames it checks for whether or not a word is really being spoken (referred to as *endpoint detection*). Assuming that a word is being spoken, the system varies the spectral sampling rate dynamically. The spectral difference of adjacent frames are then compared, and if the distance is insignificant then the frame is discarded. This technique is called *selective downsampling* and it reduces the data rate through the system, particularly the long steady-state sounds in words. The result of disregarding the insignificant frames in this manner is improved accuracy, real time vocabulary processing, and expanded template storage memory. The front end subsystem then downloads the frames into the comparator.

2. **Comparator**

As the name implies this subsystem compares the incoming frame with those already in memory. This is accomplished by a technique called *dynamic time warping*. The input frames are compared with the reference frames of the words in memory. The sum of the differences of their spectral distances is computed. A score or cost for each and every word in memory is then computed and the minimum value is sought. The lower the score computed by the algorithm the better the recognition. As discussed in Chapter 3, if the score is below a rejection threshold then the string specified for the word is output. If the word score is above this value a non-recognition occurs.

E. SUBJECTS

One civilian and one military officer participated in the testing of the SRI speech board. Both subjects were male 32 to 46 years old. The civilian (M1) was very experienced with many types and models of speech recognition systems, while the military officer (M2) had less than 12 hours total exposure to speech systems.

F. TRAINING ALGORITHM

The training was conducted in a low noise speech lab at SRI utilizing a SHURE SM-10 close-talking microphone. A training algorithm was used to develop the templates for each speaker. This speaker dependent system requires the user using the the training algorithm to specify how many training passes are desired as well as the "cluster" size and method of input. This would allow one to input utterances from a tape recording and have the algorithm form templates on a fixed number of passes from the recording. The cluster size is an averaging technique which is the essential ingredient in creating templates. To form a cluster, an initial template (the first training pass usually) is compared against another utterance for that word or phrase. The spectral distance is calculated and compared to the initial utterance(s) in memory. If the minimum average distance is less than the distance specified in the algorithm, then one template is formed. Otherwise the system will indicate that a template could not be formed since the spectral clusters were outside the limits. The trainer program then will prompt for more repetitions in an effort to generate a single template. If after three more repetitions a single template still could not be created from the additional utterances, two templates for the same word are computed. Each template and spoken word is placed alphabetically in a Unix directory. The templates are indicated by file type *.t1* while the utterances are identified by a *.u1*. For example if the word "advisory" is spoken twice in creating one template one would find the files *advisory.t1*, *advisory.u1* and *advisory.u2*. This is unique to this system and the advantages of this scheme will be evident later in this chapter.

G. THE VOCABULARY

Any vocabulary file can be created by specifying the word prompt followed by two colons, then the keystrokes or output string. This file is in the working directory and is specified when invoking the trainer algorithm. In this particular experiment the subjects used a 100 word initial vocabulary taken from the 1000 word set used by SRI (Appendix A). A second vocabulary which was used in extensive studies conducted at the Naval Postgraduate School (Poock, 1981, 1986a) was sent directly to the SUN workstation at the host (SRI-BOZO) via the DDN. This vocabulary of 240 utterances is shown on the data sheet in Appendix B. It is divided into five groups of words based on the number of syllables. There were 10% one syllable words, 30% two syllable words, 20% three syllable words, 20% four syllable words, and 20% five or more syllable words. These words were selected from commands typically used in a command center.

H. PROCEDURE AND DATA COLLECTED

Several different testing periods were scheduled over a three month period. Both subjects traveled to the SRI International building in Palo Alto, Ca. to participate in the testing. The session started by logging onto the SRI-BOZO net via the Sun Microsystems Computer terminal. The appropriate windows were displayed and the MARA system was automatically enabled during the login sequence.

The trainer program was used only once for each vocabulary. One user (M1) used three training passes while the other user (M2) only used two passes. There was no need throughout the three months to retrain the vocabularies. A selective retraining of several words was accomplished to demonstrate the ease of retraining or adding new words.

Under the main directory of *NPS* were the subdirectories of templates *POOCK.TEMPLATES* and *MIKE.TEMPLATES.* The word recognition program was enabled and the file of 100 words or 240 words was called. The program automatically searched the alphabetical subdirectories and loaded the proper templates on to the speech board. It took an average of 130 seconds to load the 240 word templates. For data collection purposes each session was recorded to a file with the lowest five words and their scores for each utterance. When possible the other subject would record errors as he witnessed them to confirm the recorded data. Additionally, any abnormalities or peculiarities the system would display would be more apparent to the observer and thus free the subject to concentrate on the word list.

In an effort to demonstrate the robustness of the system, the different lists were read with varying speeds. The vocabulary was tested forward, backward, and randomly at both a normal speaking rate and then at a significantly quicker pace. In addition, the subjects attempted to demonstrate the interoperability of the same voice patterns between the two subjects by using each others templates. A joint template was attempted but due to the relatively small spectral distance allowed in the training algorithm cluster averaging technique, after four passes no single joint template could be created.

Several runs were conducted in a noisy environment. A cassette tape of machinery noise was played at a level of 74 db(A) at the microphone. This level is considerably higher than one could expect in a command and control environment even in a shipboard tactical decision center.

The vocabulary can easily be modified by editing the file. If a file is modified to include a word not yet trained, the speech program indicates that it could not find a template for that word. Otherwise, it would load any template that was specified in the vocabulary regardless of whether or not it was trained at the same time or a part of another vocabulary.

During one of the testing periods, the subjects used a *syntactic feedback system* demonstrated by SRI to NAVELEX in July 1984. (Murveit, 1986) The syntactic feedback system is a specially designed algorithm to correct recognition errors in a sentence. The grammar is structured as a finite state machine with beginning, end, and transition states. The program would compute the least-cost path through a series of weighted arcs and then select the recognized sentence. For instance, in a data base query if a word or words were misrecognized by the recognition system, it could be corrected by the syntactic feedback algorithm.

Throughout the testing period it was evident that a good background in the UNIX operating system and familiarity of the *MARA* system were major prerequisites to effective use of the speech recognition system. Software improvements in user interaction and a well written operating manual for reference would have been helpful.

I. RESULTS

1. Accuracy

Results for the 1000 word vocabulary tests conducted by SRI reported in Murveit (1986) are shown below in Table 1. M1, M2, F1, and F2 refer to individual male and female subjects. The percentages refer to word recognition.

TABLE 1

SRI 1000 WORD RECOGNITION PERFORMANCE

M1	89-91 %
M2	89-93 %
F1	91-93 %
F2	86-90 %

The data shown in Table 2 reproduced from Murveit (1986), reflect the results of SRI's speech recognition system utilizing the TI-20-word data base used to test commercial speech recognition systems. (Doddington and Schalk, 1981)

The results of the tests conducted by our subjects appear in Tables 3 through 6. These tables represent the trials with the variability in speech speed and no maximum rejection threshold specified.

A *two sample T test* utilizing an Arcsin Transformation criteria was completed using *MINI-TAB* statistics package showing no significance between the two means of our subjects at the 0.05 level of significance. (Minitab, 1981)

2. Interoperability of Voice Patterns for Different Users

The results of the interoperability tests are shown in Table 5 showing an obvious decrease in accuracy. The computed scores or differences between the

TABLE 2

SRI TI DATA BASE PERFORMANCE (ERRORS OF 320)

16 SPEAKERS	TOTAL 13 ERRORS	.25% MEAN ERROR RATE
320 UTTERANCES EACH		

TABLE 3

NPS 100 WORD VOCABULARY TEST

M1	94-98 %	8 TRIALS	AVG 96 %
M2	91-99 %	12 TRIALS	AVG 97 %

TABLE 4

NPS 240 WORD VOCABULARY TEST

M1	95-100 %	7 TRIALS	AVG 97 %
M2	98-100 %	7 TRIALS	AVG 99 %

recognized words and the templates were on the average 10 points higher than the mean of their scores with their own templates.

TABLE 5
INTEROPERABILITY TESTS

M1 using M2 Templates	80-89 %	3 TRIALS
M2 using M2 Templates	78-86 %	3 TRIALS

3. Accuracy in a Noisy Environment

The *endpoint detection* process which is computed in the front end section of the card also keeps track of the background noise level and effectively ". . . eliminates moderate room noises and maintains proper signal levels in the converter and analysis circuits." (Murveit, 1986) The background noise elimination features of the microphone and the system allowed it to perform with virtually no degradation in recognition performance. It is interesting to note that the system was not capable of any recognition at approximately 76db(A). Table 6 shows the results in a noisy environment.

TABLE 6
NOISY ENVIRONMENT

M1	99 %	2 TRIALS
M2	96-98 %	2 TRIALS

J. SYNTACTIC FEEDBACK

The subjects during one testing session exercised the syntactic feedback system using a limited vocabulary and allowable sentence structure. There are a number of questions which are suggested by Murveit (1986). These issues should be pursued, since there is an increase in accuracy realized in using this algorithm.

K. CONCLUSIONS AND RECOMMENDATIONS

The purpose of these tests was to examine the voice recognition performance of the SRI *'Berkeley'* 1000-word discrete speech recognition board. The results of our testing confirms the results reported by SRI Project 6096. (Murveit, 1986) Their 1000-word speech recognition system is very accurate and quite fast. Throughout the entire study, no degradation of the templates occured. The experiment was conducted entirely on initial templates. Despite the variability in speaking rate, three months of broken testing, and testing in a noisy environment, the system performed proficiently.

However, the SRI *'Berkeley'* board in its present configuration does *not* meet all the requirements necessary to be a viable interface in the CCWS. In spite of commercial discrete speech recognition system vendors advertising an input rate of 60 words minute, *discrete* speech recognition systems are *not* suitable for a Command and Control environment. The user must modify his speaking rate by pausing after each utterance to effectively use the system. It would be insensitive to the ultimate users in a CCWS environment to assume that discrete utterances in a high tempo, high pressure, and possibly high threat situation is even remotely acceptable. A *connected* or even a *continuous* speech recognition system is the only suitable alternative. This gives the *Commander* the best opportunity to process information quickly and accurately allowing him more time to enact a timely and knowledgeable decision.

V. TEST, ANALYZE, AND EVALUATE A COMMERCIAL CONNECTED VOICE RECOGNITION SYSTEM IN A WARGAMING ENVIRONMENT

The previous chapter analyzed the reliability of a 1000 word *discrete* speech recognition system. The SRI speech board is a state-of-the-art system which was quite good and very accurate. The disadvantage was, of course, utilizing a *discrete* system in a command and control environment.

The purpose of this chapter is to analyze the performance of a relatively inexpensive, commercially available *continuous* speech system. The VOTAN 6050 Model II product was examined for its applicability and adaptability to a command and control environment in a particular Naval Warfare Interactive Simulation System (NWISS). VOTAN has been used in many experiments, tests, and applications and is regarded by many as a very capable speech recognizer. For example, in the Navy's air traffic control trainer and simulator this same recognizer was demonstrated and performed quite well. The VOTAN was used in this experiment to focus on four major areas:

(1) An application of a *continuous* speech system in a Command and Control environment similar to a workstation module.

(2) Investigate any significant differences in the ability to input commands by speech or keyboard entry.

(3) Investigate the possibility of utilizing a speech recognition system in Navy Tactical trainers to overcome the *dead* time in learning the game command keystrokes and entry procedures.

(4) Investigate any significant differences in speed of command entry for users with familiarity with standard Navy phraseology versus those unfamiliar with using speech recognition systems.

There is considerable time expended at every tactical trainer by the users in familiarizing themselves with the equipment and game command entry procedures. This 'dead' time could be eliminated by using a standardized vocabulary as used in Navy contact reporting procedures and incorporating speech recognition to minimize keyboard operation and special game commands. The result would be an increase in useful tactical trainer time. Before examining the VOTAN speech system we will briefly describe NWISS and the similarities to the proposed specifications for the Command and Control Workstation (CCWS).

A. DESCRIPTION OF THE NAVAL WARFARE INTERACTIVE SIMULATION SYSTEM (NWISS)

NWISS is a real-time, user-interactive simulation of naval warfare. Its mission was originally to train senior Naval Officers in force-level tactical decision making and management of command and control. The NWISS game resides on a VAX 11/780 computer, and a network of peripheral VT100/102, ADM31 terminals and RAMTEK graphics terminals to provide the necessary displays and interactive stations. The equipment is located in the Naval Postgraduate School Wargaming Analysis and Research (WAR) Laboratory. There is a sufficient amount of equipment to support three separate bays or areas to simulate disjoint command and control modules.

The equipment available in the wargaming and research laboratory is very similar to the equipment for the CCWS. The Distributed Command System (previously shown in Figure 1.1), shows the Interim Battle Group Tactical Trainer (IBGTT), which is a component to be interfaced into the local area network. NWISS is to be integrated into the IBGTT network in 1987. In applying a continuous speech capability on the NWISS, we can analyze the requirements for a continuous speech system in a C^2 environment.

The RAMTEK monitor is the display system used in the NWISS modules. The presentation is nothing more than a typical Naval Tactical Data System (NTDS) picture with some exceptions and is similar to the display envisioned for the CCWS. All ships, planes, and submarines are displayed utilizing standard Navy symbology as shown in Figure 5.1, with some differences. The exceptions to standard shipboard NTDS console display are summarized below:

- NWISS has color enhanced symbology (An excellent screen improvement).
- The track symbology in NWISS does not reflect engagement status of tracks.
- Track information is available only on display boards and is not accessible from the graphic display screen.
- Electronic (ESM) and acoustic (SONAR) emissions lines of bearing are color coded as well.
- Old tracks change to yellow to indicate a fading track.
- NWISS does not have representative symbology available in NTDS to indicate type of platform.
- NTDS has balltab capability for immediately obtaining information on the status of tracks.

The color scheme displays all known friendly forces in *blue*, enemy forces in *red*, and unknown contacts in *white*, with a fading tracks indicated in *yellow*.

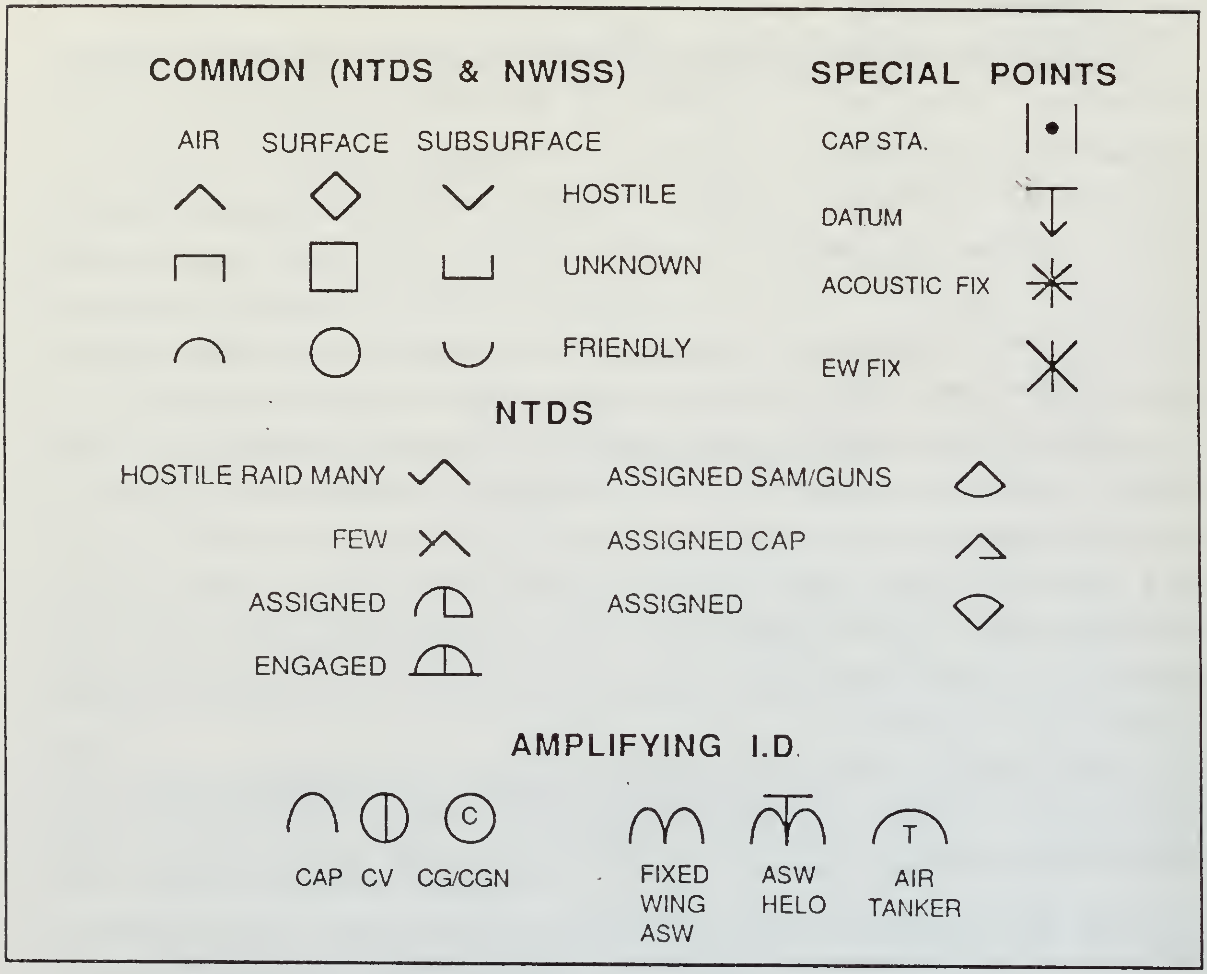


Figure 5.1 NTDS Symbology.

B. SCENARIO

The scenario for the NWISS game was designed to place subjects in situations requiring the input of many combinations of the various commands available. It was the first exposure for most of the subjects to a multi-threat Naval wargame since it was the introductory simulation course for students of the Naval Postgraduate School Command and Control curriculum. Each group of students embarked in separate aircraft carriers or command and control modules. The objective was designed to demonstrate:

- High Resolution Color Graphics
- Friendly man - machine interface
- The level of detail required to plan, run, summarize, and analyze a relatively low level wargame

- The NPS WAR Lab capabilities

Additionally, the purpose of each of the runs was to familiarize the subjects with the game and experiment with the various commands and display boards. The actual situation briefing used in these tests is included in Appendix C.

C. VOTAN SPEECH RECOGNITION SYSTEM MODEL 6050 SERIES II

The VOTAN VTR 6050 Series II is a stand alone unit which can interface with any system supporting a standard RS-232 port. It has the ability to operate in two distinct modes: Voice Terminal (VTR) and Voice Peripheral (VP). The VTR mode allows the equipment to interface directly between a terminal and a host. This is the mode that was used in the NWISS game with an ADM31 terminal and the VAX 11 780 as host. The configuration to run NWISS with the VOTAN appears in Figure 5.2. The VP mode is designed for telephone-based applications. This mode was not used in this experiment and will not be discussed.

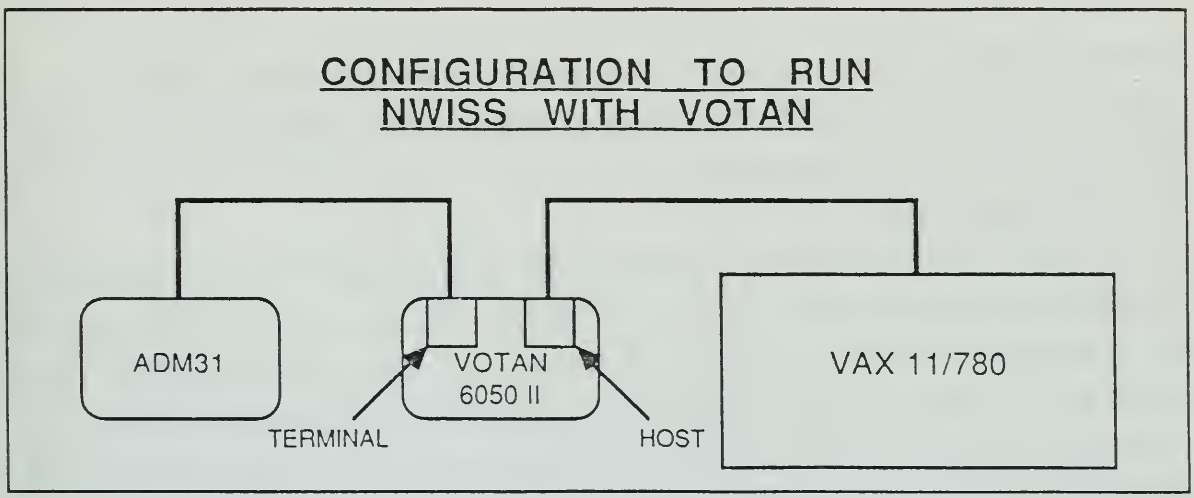


Figure 5.2 Configuration To Run NWISS With The VOTAN.

1. Vocabulary Size

The VOTAN 6050 Series II has three internal components which support its vocabulary. These are:

- VTR System Memory (approximately 500K)
- Floppy Disk Memory (maximum of 760K)
- Voice Card Memory (maximum of 22K)

In addition to these components there is also the possibility of storing voice files on the host computer. This was not used since the vocabulary was small enough to be stored directly in system memory. The average word or template uses 200-250 bytes of memory. When the system is fully loaded, there can be 2000-3000 words in main memory. It is important to note that all voice recognition takes place on the voice card. The voice card can accommodate up to 50 words (from the 2000-3000 in main memory) at a time. A tradeoff can be seen in the number of words vs. the number of templates for each word. The more accuracy required, the more templates needed for each word, and the fewer words loaded into each active set.

The main memory can contain multiple sets and takes only about 150 msec to upload sets onto the voice card memory. This can be done by tailoring the vocabulary to switch automatically upon hearing a *switch* word or can be automatically switched when a certain number of word(s) are recognized from an on-line set. A *switch* is a mnemonic that is spoken by the user to load the voice card with a specific set of templates. This file is transferred at a rate of 9600 baud. During the upload period the VTR is automatically recording speech (up to 7 secs) to be searched immediately upon completion of the swap. It is extremely fast and is virtually unnoticed by the user. It is recommended in *VOTAN Guide To Procedures*, that one should limit the number of words in a set to about 10 to 20. A set of this size will optimize recognition and provide a quicker system response time.

2. Programming

The VTR 6050 Series II can be easily programmed. The key element in optimizing the performance of the system is careful construction of the vocabulary so as not to exceed the voice card memory limitations and to mininize set changes. With the VTR in the off-line mode, (which blocks any keystrokes from going to the host), a vocabulary is entered directly onto the screen in an editor mode. The user specifies the file name and then begins entering headings for the word sets followed by the actual words in the set. The following is an example of a small file which is included to show the various programming commands available: (VOTAN GTP and UG, 1985)

```
EDT NUMBERS      *(this allows you to enter the EDITOR)
                 *(mode)
S:NUMBERS,       *(this specifies the set name NUMBERS)
NS=COLORS,       *(this is the pointer to the NEXT SET:)
                 *(COLORS which is)
```

```
CT=2,              *(automatically loaded after 2)
                   *(recognitions of this set)
CM                 *(indicates NUMBERS is a COMMON)
                   *(word always in memory)
ONE,HS=1           *(ONE is the prompt and 1 is the)
                   *(string sent to the host)
TWO,TS=2           *(TWO is the prompt and 2 is the)
                   *(string to the terminal)
THREE,TS=3\20      *(the \20 is the hexadecimal string)
                   *(for space to be)
                   *(sent to the terminal after the 3)
FOUR,HS=4          *(FOUR is the prompt and 4 is the)
                   *(string to the host)
```

Appendix D is the listing of the vocabulary used for the NWISS game and will be discussed later in the chapter.

3. **Operation**

While the VOTAN 6050 Series II is still in the off-line mode, the user's vocabulary and templates are placed into memory. In addition to the set in memory there are certain words called TASK WORDS which control operation of the VTR when it is on-line, and a collection of words in the user tailored vocabulary which can be indicated as COMMON words that are also a part of the total allowed templates on the voice card memory. The user can specify an initial word set that will be activated each time the system is initialized. Additionally, the user can specify whether or not *data buffering* should be used. Data buffering allows the system to store a predetermined number of strings or characters before outputting them to the host. Data buffering can be extremely beneficial when a user needs to verify a string of words prior to being sent. Numerous military situations require validation of codes or strings to ensure proper actions upon receipt. The default condition is immediate action when the word or phrase is recognized. These are some one time preliminary set-up inputs. Once this is accomplished the system is ready to be put in the on-line (ONL) mode. This sends the host string directly to the computer upon recognition. These keystrokes are then returned by the host and displayed on the screen. The keyboard can still be used and the VOTAN is transparent to the user when passing these keystrokes directly to the host.

4. **Training Algorithms**

The VOTAN 6050 Series II offers two types of training algorithms: single/discrete training and continuous training. In the single training mode, one template is formed after each utterance. The continuous training method extracts templates from a series of passes for each word in the set. This takes into account the coarticulation of a word at the beginning, middle, and the end of a group of words. Prior to entering the continuous training mode, the user must have at least two single trained templates available for template extraction to occur. The user specifies the set which he would like for continuous training. The algorithm then automatically selects up to ten words at a time and presents to the user a series of five of these words in random order on the screen. The user repeats all five words in a continuous manner. It will then display two columns of words if a sufficient number of words were recognized. The first column lists the words that were displayed as the prompts. The second column contains the words that the system recognized.

Several misrecognitions may be observed; however, the algorithm uses the other correctly recognized words for forming the extracted templates. This ability to develop these extracted templates enables VOTAN to make the claim of having a *continuous* recognizer. The operator can manipulate the presentation during continuous training to ascertain the progress of completion of a recognition matrix for the current set of words being trained. The matrix has three columns for each word indicating where the word occured in a string of words (i.e., beginning, middle, or end). There are some training passes where there will be an insufficient number of words recognized and the system will prompt the user to continue training a new set. After a certain number of passes or when the matrix is completely filled, the program will terminate the training of that word group and continue with the next set of ten words.

Prior to operating the system in VTR mode which transmits the output strings to the host or terminal, the user can invoke a program to test his templates and to ensure voice card storage has not been exceeded. The output display upon recognition consists of the recognized prompt characters and the recognition score. The recognition score is computed from the spectral distances between the template and the spoken word. Like the SRI system the lowest score is the best recognized word. The recognizer has a minimum recognition threshold default of 50, but the user can modify this value if desired. This level appears to be quite adequate for most applications.

D. SUBJECTS

Six male officers participated in this experiment. Five were Naval Officers from various communities. Three had previous experience with the modeled systems and were familiar with the terminology of giving similar orders. These were the individuals used in validating the area of familiarity with battle group phraseology vs. having no experience. All but one of the officers had less than 12 hours total exposure to voice recognition systems. The other officer had about 100 hours experience with various voice systems.

E. THE VOCABULARY

The vocabulary for the NWISS wargame consists of two major groups of commands: DISPLAY and ACTIVE. The DISPLAY commands control all aspects of the graphic plot as displayed on the RAMTEK monitor. The 'active' commands consist of many different orders that could be given to ships, submarines, and aircraft. There are actually a total of 230 allowed words that are recognized by the NWISS game. The NWISS game requires that the commands be ordered in a particular way. For example, after *activate*, the game would expect to see 7 different commands, and would disallow other inputs. These same words could appear in different positions in different correct commands to the host (this plurality in commands occurs throughout the vocabulary). In addition, the number of options after identifying a force name can range up to 50-60 possible commands, greatly exceeding the limitation of the voice card. This peculiarity required a more general tailoring of the vocabulary to model the NWISS word structure, since one could not tailor the vocabulary into finite sets allowing only a small number of words to follow other words. It is a similar problem experienced by SRI in formulating the valid structures used in formulating the finite states used in the syntactic feedback system. Consequently, this made it impossible to formulate the vocabulary within the memory and template limitations without multiple *switch* words.

Appendix D is the listing of the vocabulary used in this experiment. Note that there are six major vocabularies or sets: Display, Ships, Commands to Units, Numbers, Aviation, and Load. This was done to minimize the number of *switches* necessary for full use of the commands. For example, an actual voice command for activating an air search radar utilizing the VOTAN would be:

SHIPS SPRUANCE ACTIVATE AIR *NUMBERS* 1245 ENTER. (*6 secs*)

The ***bold*** words are the switch words for the two sets.

The same command by keyboard entry is:

FOR SPRUA ACTIVATE AIR 1245 <cr>

(28 keystrokes) (~ 10 sec) (NWISS, 1983)

F. PROCEDURE

The training was conducted in the C^3 WAR Lab at the same input terminal to be used for the game. A SHURE SM-10 close talking microphone was used for the training and game play. The subjects used in the experiment were trained in individual sessions on the VOTAN speech recognizer. The training took place in one session which averaged approximately 75 minutes. The enrollment started by loading copies of the commands as shown in Appendix D in active memory without any templates. An overview of how the training was to be conducted was given including proper microphone placement and description of the vocabularies.

Each subject started by generating two single trained templates for the set of NUMBERS, (this set included all numbers 0-9 and letters A-Z). The set NUMBERS was anticipated to require *continuous* training because of the extensive use of alpha-numerics in commands. Following the individual training of this set, the continuous training algorithm was invoked. Displaying the continuous training matrix during training led to the discovery that the algorithm is not sophisticated enough to determine exactly what order it should present the group if there are only a few unfilled blocks left in the matrix. This can be time consuming especially if the processor is experiencing some difficulties in developing an extraction template for a particular word. Upon completion of continuous training there were now five templates for each word in the set. It became apparent that this number would far exceed the number allowed on the speech card and therefore all single templates were erased. The remaining words were presented for two sets of single/discrete training passes.

After all word sets were trained, each set was displayed with the total number of templates and memory used. 'Task words' and 'common' words reside on the voice card at all times. In all cases, three of the six possible sets had exceeded usable memory, as shown in Table 7.

A review of the vocabulary and sets showed that 28 words were duplicated intentionally in the composition of the sets. This design redundancy was to reduce the

TABLE 7

INITIAL TEMPLATE LISTING

VOCABULARY SET	MEMORY (BYTES) AVERAGE	AVERAGE NUMBER OF TEMPLATES
TASK_WORDS	1651	8
COMMON	2916	18
NUMBERS*	18740	133 **
COMMANDS_TO_UNITS	23675	148 **
AVIATION	25382	142 **
SHIPS	8900	50
LOAD	16229	86

* SINGLE TRAINED TEMPLATES NOT INCLUDED

** EXCEEDS VOICE CARD LIMITATIONS (COMMON AND TASK_WORDS INCLUDED)

number of switches needed for the formulation of proper commands. Consequently, there were actually four separately trained templates for these words in storage. Two of these templates for these words were deleted from the active sets. In every case, an average of 45 additional templates were deleted to bring the memory and number of templates allowed within limits. The words that were reduced to only one template were those words with many syllables and that were readily recognized. The actual number removed varied according to the user and the way each word was enunciated. That is, if utterances were fairly slow, more memory was required. Table 8 depicts the average final number of templates and memory remaining in the actual individual files for all users. The final test was to invoke the trainer program and ensure there were no memory overflow or template overflow errors produced as the different sets were loaded onto the voice card. It is recognized that having to delete templates causes a corresponding decrease in recognition and is a significant limitation imposed by the system.

TABLE 8

REVISED TEMPLATE LISTING

VOCABULARY SET	MEMORY (BYTES) AVERAGE	AVERAGE NUMBER OF TEMPLATES
TASK_WORDS	1651	8
COMMON	2916	18
NUMBERS	13761	100
COMMANDS_TO_UNITS	16953	104
AVIATION	17304	95
SHIPS	8900	50
LOAD	15854	85

Each subject had no further training. At the start of the game the subject's revised templates were loaded into the recognizer. They were allowed to perform their roles by inputting commands as necessary.

The short time available to conduct the tests precluded evaluating the interoperability of data sets (i.e., one user operating from another's voice templates). Although the system was not designed to accomplish this, it is a point of interest when evaluating systems in a command and control environment. The purpose is that in the event of a mishap to the active operator a slow transition to another operator would have a negative impact on the C^2 center operation. The time to exchange vocabularies from one user to another was 62 seconds.

The level of noise in the module was not measured, but during the conduct of the exercise the noise in the groups during discussions and administration was very similar to those encountered in a real command and control center. The VOTAN gain can be easily adjusted if necessary.

Additionally, the 240 word vocabulary (Appendix B) was loaded into the VOTAN. A comparison of speech recognition accuracy of the VOATAN vs. SRI is shown in Table 9 using subject M2 from the previous tests. The 240 word vocabulary was loaded into 5 sets and with an average number of 96 templates and 19575 bytes of memory per set to simulate the conditions present for the NWISS vocabulary. It is evident from the data that exceeding the manufacturers recommendations of loading does in fact effect performance.

TABLE 9

SRI VS VOTAN 240 WORD RECOGNITION ACCURACY TEST

M2	SRI 99 %	VOTAN 97.4 %

G. RESULTS

The experiment set out to focus on four separate areas:

(1) Demonstrate an application of a *continuous* speech system.

(2) Investigate any significant differences in the ability to input commands by speech or keyboard entry.

(3) Investigate the possibility of utilizing a speech recognition system in Navy Tactical trainers to overcome the *dead* time in learning the game command keystrokes and entry procedures.

(4) Investigate any significant differences in speed of command entry of users familiar with standard Navy phraseology versus those unfamiliar with using speech recognition systems.

The results from the three separate runs and data collected with the constraints described show that the VOTAN in its present configuration was unable to adapt to this C^2 environment. This is primarily due to the limitations of storage and processing power of the voice card. The NWISS vocabulary is not suited for designing a distinct branching method of words from one set to other sets for correct formulation of commands. This inability to establish a tree architecture for correct command structure, resulted in the number of words in most sets exceeding the recommended number by 3.5 times. As discussed in the technical documentation and discussed earlier, the optimum number of 10-20 words would increase recognition and provide a quicker response time. With an average number of 55 words, the reaction time was inordinately slow and misrecognitions were higher than expected. Speed of speech input as stated by Kavaler (1986), is a function of:

- Speech rate

- The processing power of the speech recognizer
- The constraints placed on the way the user must speak (i.e., discrete vs. connected, number of 'switch words').

Subjects entering commands by voice with these constraints were confused and frustrated since the time delay for the recognition to appear on the terminal was often slower than one would expect for keyboard entry. Likewise, if a misrecognition occured at some point in the string a user would have to attempt to back out the command or cancel it and start the entire entry over again.

The design of NWISS command entry procedures has some unique human engineering advantages for keyboard entry. The host would not allow a command to be entered if it did not form a correct entry. The terminal would *beep* and inhibit any incorrect keystrokes. The user could type a question mark '?' and the list of acceptable entries would be listed. Even though this occurred in the voice entry procedure as well the user would be disappointed by the misrecognition and often forget the voice command 'help' which would output '?'. Eventually, he felt more hostility and mistrust toward the recognizer and got flustered, forgetting which set he was in and eventually cancelling the entire command again.

The frustration from a misrecognition was also attributable to the unfamiliarity with words in the sets and the proper NWISS command structure. The user usually blamed his uncertainty in the set and command structure on himself adding to more disappointment and disillusionment with the recognizer. In later trials, a combination of voice and keyboard was used by some subjects. They used voice for certain words and commands they felt comfortable with and then used the keyboard for the unfamiliar commands or for entries they felt required immediate and correct entry.

There could not be any determination of advantages in utilizing a speech recognition system in Navy tactical trainers to overcome the *dead* time in learning the game command keystrokes and entry procedures. The human engineering in the design of this particular wargaming system was extremely helpful both in providing assistance and prompts, as well as accepting as few as four keystrokes for certain commands. Further study is required in this area.

The subjects with some familiarity with wargaming had a distinct advantage over those who did not, both with and without voice entry. This advantage could not be directly attributed to the voice recognition application but was quite evident in the level of play. They were more comfortable at the input terminal and were relied upon by the other members in the group for advice to interpret the displays.

H. CONCLUSIONS AND RECOMMENDATIONS

Even though initially the VOTAN seemed very promising and an excellent candidate for a C^2 environment, this speech recognizer is not well suited for CCWS. It failed because the vocabulary limits of the voice card and the processing power of this recognizer were exceeded by the demands of the NWISS vocabulary. Consequently, the recognition and output speed were jeopardized. The large 1000 word vocabulary and real-time processing is necessary in the CCWS application for data base queries. Additionally, the user is required to memorize which set is active and the 'switch' words needed to enter the various sets. The user using the VOTAN must adapt his speech to the recognizer which is unacceptable. The recognizer must be an extension of the commander not a hinderance.

The combination voice and keyboard entry employed by some of our subjects during the end of the testing indicates a possible area for future study. The application of speech entry in conjunction with keyboard, mouse, or balltab manipulation should be investigated. The balltab is the exclusive device for an NTDS console in a shipboard command and control center. This would allow a smaller, more tailored vocabulary integrated into existing systems to aid the user, particularly if that individual *must* be positioned at a console or terminal.

VI. CONCLUSIONS

It is intuitive that the commander who can manage and process the tremendous flow of battle information the fastest will have more time to determine a response or make decisions which are always ahead of his adversary. As the dependency of the commander on computing resources increases, it is only natural to expect greater demands upon the man-machine interface. By including a speech recognition system on the CCWS, the commander would realize a faster information processing rate. This would result in the commander acquiring more knowledge in a faster time on which to base his decision. As Sun Tzu, the famous Chou Dynasty philosopher and military strategist once stated ". . . knowledge is power and permits the wise to conquer without bloodshed and to accomplish deeds surpassing all others."

This thesis evaluated the performance of a state-of-the-art 1000 word discrete template matching system and a commercially available VOTAN continuous speech recognition system. The requirements specified for the CCWS were:

- Large vocabulary (capacity > 1000 words).
- Real-time response.
- Very high recognition accuracy (> 98%).
- Adaptable to the user. (i.e., the user should not have to modify or alter his speaking rate significantly)
- No deterioration in accuracy in noisy and stressful environments.

The systems evaluated in this thesis did not fulfill *all* the requirements for the speech application in the CCWS. Each system had its advantages and disadvantages which were discussed in the conclusion of each respective chapter. Currently, there is not a system commercially available capable of meeting all these requirements.

Even though neither system met all the requirements established for the CCWS, recent literature reflects the improvements in the Strategic Computing Program, in particular, phonetic recognition. Speech systems capable of meeting and exceeding these specifications are not far away. In fact, CINCPACFLT is scheduled to test and evaluate the speech recognition system being developed by the Strategic Computing Program. (Strategic Computing, 1985)

As computers become more and more capable of displaying, storing, and processing information, it is only natural to assume that the interface between the user and computer should be optimized. We all can recount from our own experiences, ". . . the costs of poorly designed interfaces. Coming in many forms, the cost can include degraded user productivity, user frustration, increased training costs, and the need to redesign . . ." (Foley, 1984). For these very reasons, the design of every interface for an interactive user-computer must be of utmost importance. Speech recognition has long been thought of as the ideal interface and must be considered for all future systems.

APPENDIX A

SRI 100 WORD VOCABULARY

a
able
aboard
about
above
accept
according
account
across
act
both
bottom
box
break
bring
broken
brought
Brown
building
built
development
did
didn't
different
difficult
dinner
direction
discovered
distance
do
for
foce
forced
foreign
forget
form
forty
forward
found
for
I'd
I'll
I'm
I've
idea
ideas
if
immediately
important
impossible
manner
many
March
mark
market
Mary
material
matter
may
maybe
our
out
outside
over
own
page
paid
paper
Paris
part
right-paren
river
road
Robert
room
rose
round
run
running
said
steps
still
stock
stone
stop
stopped
store
story
straight
street
U.S.
under
understand
union
university
unless
until
up

APPENDIX B
240 WORD VOCABULARY

one
two
yankee
air_routes
Gary_Poock
load_the_gun
carriage_return
load_the_server
Iran
Japan
Sweeden
Europe
login_Poock
level_two
accat_title
strait_of_Hormuz
load_gld3
connect_to_charlie
Poock_NPS_password
change_directory_to_hunter
three
four
logout
graphics
red_sphere
steam_plant
zero
seven
November
move_it_down
use_that_one
spirograph
Captain_Ebbert
close_out_charlie
up_in_detail
United_States
level_two_viewer
North_Atlantic_Map
genisco_zero_parameters
Mediterranean_Chart
five
six
alpha
bravo
charlie
delta
echo
foxtrot
juliett
romeo
move_it_left
sierra
San_Francisco
application
engineering
human_factors
voice_technology
central_expressway
Russian_version_of_Hormuz
file_transfer_protocol
eight
nine

hotel	india
kilo	lima
oscar	pappa
move_it_right	uniform
Vietnam	Korea
advisory	interactive
business_meeting	continuous
speech_recognition	continuous_speech
efficient_transmission	system_integration
golf	mike
quebec	tango
victor	whiskey
xray	zulu
move_it_up	Bangladesh
Tokyo	Hollister
down_in_detail	corporation
criteria	advantages
suitability	radiology
identification	automatic_recognition
course	speed
command	attack
bingo	report
proceed	station
altitude	recover
relocate	designate
available	plot_esm
track esm	designate_track
command_and_control	probability
enemy_detection	probability_of_detection
launch	fire
cancel	message
bearing	label
orders	copy
satellite	envelope
negative	correlate

combination
maneuver_delay
Task_Force_Commander
proceed_to_New_Delhi
time
surface
minefield
shore_based
execute
enemy
Connecticut
Oklahoma
California
place_a_marker_on_Paris
bingo_all_craft_immediately
neutral
sensor
Stockton
air_field_name
track_friendly
bearing_and_distance
Minnesota
Eisenhower
relocate_the_Sunfish
take
Georgia
Texas
Utah
latitude
Ohio
flight_controller
Pango_Pango
lay_a_barrier
attack_barrier_target
scope
sensor_delay
Alabama
North_Carolina
place_a_circle_on_Moscow
shoot
refuel
distance
contact
submarine
order_name
Indiana
Pennsylvania
South_Dakota
map
grid
missile
Adak
New_York
track_unknown
track_neutral
Louisiana
Colorado
New_Mexico
refuel_the_Connie
place
Vermont
Daniels
platform
longitude
torpedo
Trans_World_Airlines
keep_on_station
ground_control_approach
Atlantic_Data_Base
drop

Bangkok
Brisbane
Antwerp
Arkansas
user's_guide
Acapulco
Yokohama
Diego_Garcia
Pacific_Data_Base
Maine
Portland
Aspro
red_fox
blue_force_one
Baltimore
Sevastopol
chronometer
plot_all_submarines
Iberian_Carrier

Bombay
Canton
Africa
Saigon
Kitty_Hawk
Vladivostok
Sea_of_Japan
Indonesia
Arabian_Tanker
save
Rangoon
Kiev
Naples
Calcutta
Wyoming
Honolulu
John_Kennedy
United_Air_Lines
West_German_Torpedo

APPENDIX C

SCENARIO BRIEFING

FROM: COMSEVENTH FLEET

TO: COMMANDER, TASK GROUP ONE PT ONE
COMMANDER, TASK GROUP ONE PT TWO

OPORDER 00003

1. THIS MESSAGE CONSTITUTES AN OPERATION ORDER FOR CTG ONE PT ONE AND ONE PT TWO. IT CONSISTS OF GEOPOLITICAL BACKGROUND, COMPELLING EXECUTION OF OPERATION, TASK FORCE ORGANIZATION, OPERATION OBJECTIVES, SUMMARY OF OPPOSING FORCES, AND DIRECTION CONCERNING CONDUCT OF OPERATION.

2. DURING THE LAST 48 HOURS THE CVBGS HAVE DRAWN NEAR TO EACH OTHER AND NOW MAY BE ORGANIZED INTO A TASK FORCE OF CONSIDERABLE SIZE. AS LIGHT DAWNS THE JFK HAS RECOVERED THE LATE NIGHT LAUNCH WHICH WAS CYCLIC DUE TO THAT CARRIERS CLOSER PASSAGE TO ENEMY LAND BASES AND DUE TO THAT THE JAPANESE ISLANDS THAT COULD NOT BE ASSUMED TO BE FRIENDLY. THE AIR COMPLEMENT HAS BEEN AT WORK FOR AT LEAST 48 HOURS. KITTY ON THE OTHER HAND HAS JUST LAUNCHED A CAP GRID WHICH IS PROCEEDING TO POSITION. IT INCLUDES AN E2 AND AN S3.

A. AN E3A (AWACS) WAS SUPPOSED TO ARRIVE ON STATION OUT OF ADAK ON AN AIR FORCE MISSION ABOUT ONE HOUR AGO. HOWEVER SHE HAD NO REPORTING RESPONSIBILITY TO THE OTC AND HER PRESENCE HAS NOT AS YET BEEN CONFIRMED. P3S ARE DEPLOYED IN SUPPORT HOWEVER.

TASK GROUP ONE PT ONE CONSISTS OF THE FOLLOWING SHIPS LOCATED 12 HOURS PRIOR TO THE START OF YOUR RUN FOR RECORD AS FOLS:

• USS KITTYHAWK	46-30N/157E (APPROX)
• USS WICHITA	"
• USS KNOX	"
• USS SPRUANCE	"
• USS RATHBURNE	"
• USS WILSON	"
• USS MCCORMICK	"
• USS FOX	"
• USS LOS ANGELES	"
• USS OMAHA	SOJ

- PATRON FOUR SIX IN PLACE MISAWA AB, 40-00N 141-50E.
- PATRON SEVENTEEN IN PLACE, ADAK AB, 51-50N 176-30W.
- UNSUBORDINATED AWACS DET IN PLACE, ADAK.

CVBG 1.2, JFK TASK GROUP CONSISTS OF THE FOLLOWING UNITS:

• USS JOHN F. KENNEDY	46-30N 155E (APPROX)
• USS IOWA	"
• USS LONG BEACH	"
• USS JOHN ROGERS	"
• USS TURNER JOY	"
• USS JOHN HANCOCK	"
• USS MAC	"
• USS FURER	"
• USS GAR (NEW CONSTRUCTION SSN)	SOJ

4. OPERATIONAL OBJECTIVES: (A REPEAT)

THE SEA OF OKHOTSK AND THE BASES WHICH SURROUND IT PROVIDE A PRIMARY SANCTUARY FOR THE SOVIET FAR EASTERN FLEET. PROCEED TO A POSITION FORM WHICH YOUR COMBINED FORCES CAN INTERDICT SURFACE AND SUBSURFACE FORCES AND LAUNCH STRIKES AGAINST THE SOVIET LAND BASED AIR STRONGHOLDS. PREPARE TO FIGHT YOUR WAY IN AND STAY AS LONG AS POSSIBLE.

- PRIMARY MISSION ONE

PLAN FOR AND BE PREPARED TO CONDUCT A PREEMPTIVE AIR RAID ON PETRO WHEN IN POSITION AND WHEN DIRECTED BY HIGHER AUTHORITY.

- PRIMARY MISSION TWO

SEARCH FOR, IDENTIFY AND REPORT, THE SOVIET MINSK BG, AND ANY RED SUBMARINES WHICH MAY BE ENCOUNTERED. BE PREPARED TO CONDUCT SHORT NOTICE PREEMPTIVE ATTACK ON THESE FORCES WHEN DIRECTED BY HIGHER AUTHORITY.

5. SUMMARY OF OPPOSING FORCES: ANTICIPATED OPPOSING FORCES CONSIST OF THE SOVIET TASK GROUP COMPRISED OF:

- . ONE MINSK CLASS CGH
- . ONE KASHIN CLASS CGL
- . ONE KREST II CLASS CG
- . TWO VICTOR CLASS SSN
- . TWO CHARLIE CLASS SSGN
- . ONE ECHO2 CLASS SSGN
- . INTELLIGENCE SOURCES INDICATE POSSIBILITY THAT ADDITIONAL SURFACE UNITS OF UNKNOWN TYPE MAY HAVE DEPARTED VLADIVOSTOK WITHIN THE PAST 36 HOURS, ALTHOUGH THIS IS , AS YET, UNCONFIRMED.

24 HOURS PRIOR TO THE START OF YOUR RUN FOR RECORD, THE SURFACE FORCES WERE IN THE SEA OF OKHOTSK. IT IS ANTICIPATED THAT ONE SUB WILL CONTINUE WITH THE SOVIET BG.....DURING THE LAST 36 HOURS ONE HOSTILE SSN HAS BEEN DETECTED IN THE VICINITY OF KITTY. EVASIVE ACTION AND BEST SPEED MAY HAVE LEFT IT BEHIND FOR THE TIME BEING, HOWEVER, SPEED OF TASK GROUP ADVANCE HAS BEEN SLOWED AND VIGILANCE TO THE REAR IS ADVISED. THE CONTACT THOUGHT TO BE SHADOWING THE JFK WAS NEVER CONFIRMED BY CVBG FORCES OR THE FURER ON HER TRIP

NORTH. THE REMAINING SUBS ARE EXPECTED TO BE IN POSITION TO OPPOSE YOUR TRANSIT NEAR THE ISLAND PASSAGES NOTHEAST OF HOKKAIDO. INTEL STILL ESTIMATES THE GREATEST THREAT WILL BE FROM (1) LAND BASED AIR OF REGIMENTAL SIZE GROUPINGS, AND (2) FROM SSNs THAT ARE CURRENTLY DEPLOYED OR WILL DEPLOY SHORLY. THE SOVIET TASK GROUP CAN BE EXPECTED TO OPPOSE ENTRY TO THE SEA OF O TO SOME DEGREE.

6. DIRECTION CONCERNING THE CONDUCT OF THE OPERATION: THE CONDUCT OF THE OPERATION IS AT THE DISCRETION OF THE OFFICER IN TACTICAL COMMAND WITHIN THE FOLLOWING CONSTRAINTS AND POLICY GUIDANCE:

1 DEFCON CONDITION TWO. WE ARE NOT AT WAR. IF POSSIBLE, AVOID ACTIONS WHICH COULD PROVOKE A WAR. CONFIRM AS EARLY AS POSSIBLE WHICH COMMANDER CVBG 1.1 OR CVBG 1.2, WILL BE OTC. KITTY IS STILL THE ONLY SHIP WITH KEYING MATERIAL NECESSARY TO GAIN LAND BASED AIR SUPPORT FROM ADAK (THIRD FLEET) AND MISAWA (SEVENTH FLEET). EXPECT LATE BREAKING GUIDANCE FROM THIS HEADQUARTERS AS EVENTS IN EUROPE COULD SIGNAL THE START OF ACTIONS IN THIS THEATRE.

2 WEAPONS ARE TIGHT AT THIS TIME. WEAPONS FREE STATUS MUST BE REQUESTED FROM ORIG UNLESS ATTACKED, IN WHICH CASE RESPONSE IN KIND ONLY IS AUTHORIZED. THAT IS TO SAY THAT THE LOSS OF AN AIRCRAFT MAY NOT BE RESPONDED TO BY AN ATTACK ON A SHIP. MINIMIZE ESCALATING ACTIONS.

- THE FIRST CHALLENGE WILL BE TO ORGANIZE THE COMBINED TASK GROUP INTO AN EFFICIENT FIGHTING UNIT. NOTIFY THIS HEADQUARTERS OF ALL SIGNIFICANT DECISIONS. YOUR PLAN OF OPERATIONS, IN BRIEF, IS OF PRIMARY INTEREST.
- TO ENSURE SUSTAINABILITY IN THE EVENT OF A PROTRACTED CAMPAIGN ONLY 36 AIRCRAFT MAY BE AIRBORNE AT ANY GIVEN TIME FROM EACH CARRIER (TOTAL OF 72). THIS DOES NOT INCLUDE LAND BASED P3s OR AWACS A/C UNDER THE CONTROL

OF THE CARRIER. PERMISSION TO USE THIRD FLEET ASSESTS MUST BE GAINED FROM THIRD FLEET, VIA SEVENTH FLEET, PRIOR TO ISSUING A LAUNCH COMMAND.

SUBMIT YOUR PLAN OF ACTION PRIOR TO THE RUN FOR RECORD CONTAINING:

1 BELIEVED ENEMY INTENTIONS:
2 YOUR INTENTIONS:
3 CONTINGENCY PLANS:

APPENDIX D
VOTAN VOCABULARY FOR NWISS

This file is the vocabularies set up for the interactive battle group game in the war lab.

COMMON WORDS SET

001 COMMON
WRONG
ENTER
HELP
DISPLAY
COMMANDS_TO_UNITS
NUMBERS
AVIATION
SHIPS
LOAD

TASK WORDS SET

002 TASK_WORDS
GO_TO_SLEEP
LISTEN_TO_ME
INITIALIZE
VERIFY

003 WRONG,HS=\0B,CM

004 ENTER,HS=\0D,CM

006 HELP,HS=?,CM

DISPLAY WORDS SET

008 DISPLAY,CM
CANCEL,HS=CANCEL\20
CIRCLE,HS=CIRCLE\20
GRID,HS=GRID\20
RADIUS,HS=RADIUS\20
SHIFT,HS=SHIFT\20
DESIGNATE,HS=DESIGNATE\20

```
XMARK,HS=XMARK\20
CENTER,HS=CENTER\20
FORCE,HS=FORCE\20
POSITION,HS=POSITION\20
DROP,HS=DROP\20
ERASE,HS=ERASE\20
ESM,HS=ESM\20
PLOT,HS=PLOT\20
LINE_OF_BEARING_SONAR,HS=LOB_SONAR\20
LINE_OF_BEARING_ESM,HS=LOB_ESM\20
BEARING,HS=BEARING\20
BACKSPACE,HS=\08
SPACE,HS=\20
TRACK,HS=TRACK\20
OLD,HS=OLD\20
SONAR,HS=SONAR\20
PLACE_A,HS=PLACE\20
```

COMMANDS TO UNITS SET

```
009 COMMANDS_TO_UNITS.CM
TIME,HS=TIME\20
AIR,HS=AIR\20
RADAR,HS=RADAR\20
EMITTER,HS=EMITTER\20
ALTITUDE,HS=ALTITUDE\20
BEARING,HS=BEARING\20
POSITION,HS=POSITION\20
BLIP_ON,HS=BLIP ON\20
COURSE,HS=COURSE\20
OFF,HS=OFF\20
DESIGNATE,HS=DESIGNATE\20
FRIENDLY,HS=FRIENDLY\20
UNKNOWN,HS=UNKNOWN\20
EXECUTE,HS=EXECUTE\20
LAUNCH,HS=LAUNCH\20
PERISCOPE,HS=PERISCOPE\20
CHAFF,HS=RBOC\20
SUBMARINE,HS=SUBMARINE\20
HANDOVER,HS=HANDOVER\20
JOIN,HS=JOIN\20
RECOVER,HS=RECOVER\20
SEARCH,HS=SEARCH\20
ACTIVATE,HS=ACTIVATE\20
SURFACE,HS=SURFACE\20
ESM,HS=ESM\20
SONAR,HS=SONAR\20
BARRIER,HS=BARRIER\20
FORCE,HS=FORCE\20
TRACK,HS=TRACK\20
BLIP_OFF,HS=BLIP OFF\20
COVER,HS=COVER\20
DEPTH,HS=DEPTH\20
ENEMY,HS=ENEMY\20
NEUTRAL,HS=NEUTRAL\20
EMCON,HS=EMCON\20
FIRE,HS=FIRE\20
ORDERS,HS=ORDERS\20
PROCEED,HS=PROCEED\20
REFUEL,HS=REFUEL\20
CEASE,HS=CEASE\20
INFORM,HS=INFORM\20
RECALL,HS=RECALL\20
REPORT,HS=REPORT\20
SILENCE,HS=SILENCE\20
```

TURN,HS = TURN\20
USE,HS = USE\20
SPACE,HS = \20
BACKSPACE,HS = \08
SPEED,HS = SPEED\20
STATION,HS = STATION\20
TAKE,HS = TAKE\20
ALL,HS = ALL\20
ON,HS = ON\20
DECEPTIVE_COUNTER_MEASURES,HS = DECM\20
WEAPONS_FREE,HS = WEAPONS FREE\20
WEAPONS_TIGHT,HS = WEAPONS TIGHT\20

NUMBERS SET

010 NUMBERS,CM
ONE,HS = 1
TWO,HS = 2
THREE,HS = 3
FOUR,HS = 4
FIVE,HS = 5
SIX,HS = 6
SEVEN,HS = 7
EIGHT,HS = 8
NINER,HS = 9
ZERO,HS = 0
POINT,HS = .
NORTH,HS = N\20
SOUTH,HS = S\20
EAST,HS = E\20
WEST,HS = W\20
TACK,HS = -
ALPHA,HS = A
BRAVO,HS = B
CHARLIE,HS = C
DELTA,HS = D
ECHO,HS = E
FOXTROT,HS = F
GOLF,HS = G
HOTEL,HS = H
INDIA,HS = I
JULLIET,HS = J
KILO,HS = K
LIMA,HS = L
MIKE,HS = M
NOVEMBER,HS = N
OSCAR,HS = O
PAPA,HS = P
QUEBEC,HS = Q
ROMEO,HS = R
SIERRA,HS = S
TANGO,HS = T
UNIFORM,HS = U
VICTOR,HS = V
WHISKEY,HS = W
X-RAY,HS = X
YANKEE,HS = Y
ZULU,HS = Z
SPACE,HS = \20
BACKSPACE,HS = \08

AVIATION SET

```
011 AVIATION,CM
    ALTITUDE,HS = ALTITUDE\20
    BEARING,HS = BEARING\20
    POSITION,HS = POSITION\20
    BINGO,HS = BINGO\20
    COURSE,HS = COURSE\20
    FIRE,HS = FIRE\20
    LAUNCH,HS = LAUNCH\20
    AEW,HS = AEW\20
    ASW,HS = ASW\20
    RECONN,HS = RECONN\20
    RESCUE,HS = RESCUE\20
    STRIKE_CAP,HS = STRCAP\20
    SURCAP,HS = SURCAP\20
    JAMMER,HS = JAMMER\20
    NONE,HS = NONE\20
    SPEED,HS = SPEED\20
    PROCEED,HS = PROCEED\20
    STOP,HS = STOP\20
    FOR,HS  = FOR\20
    CH46,HS = CH46\20
    E3A,HS = E3A\20
    EP3E,HS = EP3E\20
    FA18,HS = FA18\20
    P3C,HS = P3C\20
    LAMPS,HS = SH2F\20
    SPACE,HS = \20
    BARRIER,HS = BARRIER\20
    FORCE,HS = FORCE\20
    TRACK,HS = TRACK\20
    TO,HS = TO\20
    COVER,HS = COVER\20
    AT,HS = AT\20
    MISSION,HS = MISSION\20
    AIRTANKER,HS = AIRTANKER\20
    DECOY,HS = DECOY\20
    RELAY,HS = RELAY\20
    SEARCH,HS = SEARCH\20
    SURVEILANCE,HS = SURVEILANCE\20
    CAP,HS = CAP\20
    STRIKE,HS = STRIKE\20
    REFUEL,HS = REFUEL\20
    TAKE,HS = TAKE\20
    STATION,HS = STATION\20
    A6E,HS = A6E\20
    A7E,HS = A7E\20
    E2C,HS = E2C\20
    EA6B,HS = EA6B\20
    F14A,HS = F14A\20
    KA6D,HS = KA6D\20
    S3A,HS = S3A\20
    SH3H,HS = SH3H\20
    BACKSPACE,HS = \08
```

SHIPS SET

```
012 SHIPS,NS = COMMANDS_TO_UNITS,CT = 1,CM
    KITTYHAWK,HS = FOR KITTY\20
    FOX,HS = FOX\20
    WILSON,HS = FOR WILSO\20
    SPRUANCE,HS = FOR SPRUA\20
```

KNOX,HS = FOR KNOX\20
WONSAN,HS = FOR WONSA\20
LOS_ANGLES,HS = FOR LOSAN\20
MISSAWA,HS = FOR MISAW\20
ADAK,HS = FOR ADAK\20
JFK,HS = FOR JFK\20
R.K.TURNER,HS = FOR TURNR\20
MAC,HS = FOR MAC\20
FURER,HS = FOR FURER\20
IOWA,HS = FOR IOWA\20
LONGBEACH,HS = FOR LONGB\20
IOWA,HS = FOR IOWA\20
GAR,HS = FOR GAR\20
PETRO,HS = FOR PETRO\20
OMAHA,HS = FOR OMAHA\20
JOHN_ROGERS,HS = FOR ROGER\20
RATHBOURNE,HS = FOR RATHB\20
WICHITAU,HS = FOR WICHI\20
ALEKSIUV,HS = FOR ALEKS\20
VLADIVOSTOK,HS = FOR VLAD\20
MCCORMICK,HS = FOR MCCOR\20
JOHN_HANCOCK,HS = FOR HANCK\20

LOAD SET (WEAPON SET)

013 LOAD,HS = LOAD\20,CM
HARPOON,HS = HRPON\20
TASM,HS = TASM\20
TLAM,HS = TLAM\20
APAM,HS = APAM\20
ASROC,HS = ASROC\20
MARK46,HS = MK46\20
MARK46A,HS = MK46A\20
MARK48,HS = MK48\20
MARK57,HS = MK57\20
MARK82,HS = MK82\20
MARK83,HS = MK83\20
MARK84,HS = MK84\20
76MILLIMETER,HS = MM76\20
PHIONEX,HS = PHENX\20
ROCKEYE,HS = RKEYE\20
SHRIKE,HS = SHRIK\20
SPARROW,HS = SPAR\20
SIDEWINDER,HS = SWDR\20
WALLEYE,HS = WALLI\20
SM2ER,HS = SM2ER\20

ONE,HS = 1 TWO,HS = 2
THREE,HS = 3 FOUR,HS = 4
FIVE,HS = 5 SIX,HS = 6
SEVEN,HS = 7 EIGHT,HS = 8
NINER,HS = 9 ZERO,HS = 0
PINGER,HS = SSQ47\20 DIFAR,HS = SSQ53\20
DICASS,HS = SSQ62\20 SPACE,HS = \20
BACKSPACE,HS = \08
STANDARD_EXTENDED_RANGE,HS = STDER\20
STANDARD_MEDIUM_RANGE,HS = STDMR\20

LIST OF REFERENCES

Barr, Avron, and Edward A. Feigenbaum, 1981: *The Handbook of Artificial Intelligence*, Vol. 1, HeurisTech Press, 409 pp.

Druzhinin, V. V., and D. S. Kontorov, 1972: Foreword to the Russian Edition of *Concept, Algorithm, Decision (A Soviet View)*, by S. M. Shtemenko (General of the Army, U.S.S.R.), Superintendent of Documents, U.S. Government Printing Office, Catalog No. D301.79:6, Stock No. 008-070-0034409.

Dupuy, Col. T. N., USA, Ret., 1986: In Search Of An American Philosophy of Command and Control. A Preliminary Draft, Class Notes OS3636, Summer Quarter, 25 pp.

Foley, James D., Victor L. Wallace, and Peggy Chan, 1984: The Human Factors of Computer Graphics Interaction Techniques. *IEEE*, Computer Graphics and Applications, November, 13-43.

Harris, C., L. Lane, P. Shaha, and J. Tombrella, 1983: NWISS, Naval Warfare Interactive Simulation System Users Manual. *Warlab Handout.* Naval Postgraduate School, 28 November, 17 pp.

Kavaler, Robert A., 1986: The Design and Evaluation of a Speech Recognition System for Engineering Workstations. Ph.D. dissertation, University of California, Berkeley, 162 pp.

Kurzweil, Raymond, 1984: The Coming Age of Intelligent Machines or "What is 'AI' Anyway?". *Keynote Address The Institute of Electrical and Electronics Engineers (IEEE) International Conference on Computer Design*, 14 pp.

Local Command Center Network (LCCN) Statement of Work for Request for Proposal, 23 October 1978.

Miller, G. A., 1956: The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63, 81-97.

Murveit, Hy and Donald Bell, 1986: *Speech Entry to a Natural-Language-Accessed Data Base.* SRI Project 6096, Contract N0039-83-K-0442. Menlo Park, CA: SRI International, 75 pp.

Naval Ocean Systems Center (NOSC), 1985: Navy Exploratory Development Program FY 86 Block Plan. *Combat Direction, N02C*, 15 August, 1-37.

Orr, George E., 1983: *Combat Operation C^3I: Fundamentals and Interactions.* Maxwell Air Force Base, AL: Air University Press, 99 pp.

Pallett, David S., 1985: Performance Assssment of Automatic Speech Recognizers. *Journal of Research of the National Bureau of Standards.* 90, 5, 371-387.

Poggio, A., J.J. Garcia Luna Aceves, E.J. Craighill, D. Moran, L. Aguilar, D. Worthington, and J. Hight, SRI International, 1985: CCWS: A Computer-Based Multimedia Information System. *IEEE*, October, 92-103.

Poock, Gary K, 1980: *Experiments With Voice Input For Command and Control: Using Voice Input To Operate A Distributed Computer Network.* Naval Postgraduate School, Monterey, CA, 34 pp.

Poock, Gary K., 1981: *A Longitudinal Study of Computer Voice Recognition Performance and Vocabulary Size.* Naval Postgraduate School, Monterey, CA, 32 pp.

Poock, Gary K., 1986a: A Longitudinal Study of Five Year Old Speech Reference Patterns. *Journal of the American Voice Input/Output Society.* 3, 13-18.

Poock, Gary K., 1986b: Speech Recognition Research, Applications and International

Efforts. Invited Paper for the 1986 Human Factors Society, not yet published.

Ryan, Jr., Thomas A., Joiner, Brian L., and Barbara F. Ryan, 1981: *Minitab Reference Manual.* University Park, PA, The Pennsylvania State University, 154 pp.

Salfer, D. L., 1985: Voice Automation of Ship Control. Master's Thesis, Naval Postgraduate School, Monterey, CA, September, 59 pp.

Strategic Computing Program, 1985: Chapter 2, Integration, Transition, and Performance Evaluation of Speech Technology. Draft Copy. December.

Tanenbaum, A. S., 1981: *Computer Networks.* Prentice-Hall, Inc., 517 pp.

U.S., Joint Chiefs of Staff, Publication Number 1, 1984: *Department of Defense Dictionary of Military and Associated Terms.* U.S. Government Printing Office, 404 pp.

VTR 60x0 Series II, 1985: *VOTAN Manufacturer's Technical Manual, Guide To Procedures.* VOTAN, Fremont, CA, 81 pp.

VTR 6050 II, 1985: *User's Guide, VOTAN Manufacturer's Technical Manual, Reference Manual.* VOTAN, Fremont, CA, 178 pp.

Wohl, Joseph G., 1981: Force Management Decision Requirements for Air Force Tactical Command and Control. *IEEE Transactions on Systems, Man, and Cybernetics.* SMC-11, 9, 618-639.

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